ART. IV.—*The Formation of Vegetable Mould through the Action of Worms, with Observations on their Habits.* By CHARLES DARWIN, LL.D., F.R.S. With Illustrations. Fourth Thousand. Murray. 1881.

WHATEVER may be thought of Mr. Darwin's theories, and of the opinions with which he has been more or less unfairly credited, no one can deny that of all our scientists he is the most painstaking. Feeling that the views which he takes of the order and progress of nature can only be based on a multitude of very minute facts, he set himself from the beginning to observe and record such facts. And in painstaking industry and minuteness of observation he has seldom been equalled, even by the most laborious Germans. We may accept or reject the doctrine of natural selection; but the book in which it is broached and supported by a patient investigation of the variations in pigeons and other tame creatures, is a monument of unsurpassed industry. It is one thing to assert that because all tame pigeons are undoubtedly descended from the wild blue-rock, although the structural differences between some of them are greater than those between many so-called species, therefore there is no such thing as species. It is quite another thing to appreciate the patience with which fact after fact is noted, seized on, and put into its place in the great array of evidence whereby Mr. Darwin has shown how wide is the range of variation, and how dependent it is on modifiying conditions.

The charge against Mr. Darwin, strenuously repudiated by some who claim to be his faithfullest interpreters, is that in formulating the "survival of the fittest," and the "selection of species," he not only puts aside the Mosaic account of the creation, dispensing altogether with a Creator in our ordinary sense of the word, but that his doctrine makes design superfluous, seeing that the existing races of animals are therein supposed to be the outcome of a struggle against circumstance. Of course Mr. Darwin's defenders reply that, though he says nothing about conscious design, such design may well be supposed to lie at the bottom of the selection, to shape the modifying circumstances, to

impress on each monad its selective tendency, its power of development. Such apologists add that a doctrine of this kind enhances the glory of the Creator, and gives us a grander idea of His work and His foresight than does the usual anthropomorphic interpretation of the Biblical record. But into questions of this kind we have no intention of entering; we will not pause to inquire how such views can be held by men who set up as sticklers for orthodoxy; we will not inquire how it is that there seems a sort of alliance between ritualist tendencies and the theory of development. Our present business is with Mr. Darwin's latest work, in which the most superficial reader cannot fail to notice a somewhat different tone from that which has been assumed to pervade his other books. The difference is just this: on the "survival of the fittest" theory there is no need for anticipatory purpose, and therefore Mr. Darwin was silent about it; but the earthworm's work, distinctly not for his own advantage, but for the good of other creatures, and, in the final issue, of man, evidently suggests far-reaching design. Here is a creature which for ages before man appeared on the earth has been forming vegetable mould, largely modifying the distribution of soil on the earth's surface, and doing this in a way which, as far as itself is concerned, is most wasteful. Every worm passes through its gizzard (for earthworms are furnished with such an appendage, though mud and water worms have them not) some twenty ounces of earth every year, an enormous quantity for such a minute creature to triturate; and out of this mass it gets not the largest possible amount of nutriment, as it ought to do on the "survival" principle, but a relatively trifling amount compared with what it might get were it to feed at or near the surface. The worm, then, from its own standpoint, is working most wastefully; what it does is economic work only in reference to the higher organisations whose needs it subserves. By very hard work for very little pay (so to speak) it has been for ages enriching the surface-soil, preparing it in a most remarkable manner for the growth of food-plants; working out, in fact, part of the great plan, known to and prearranged from the beginning by the great Creator. This seems to wholly cut off Darwinism from those theories which would make our *cosmos* the result of blind forces working without any guiding or informing mind. In fact, since the book before us has been published, some writers (notably one in

the *Spectator* of October 22nd) have sounded a note of triumph, as if Mr. Darwin was henceforth to be classed with the authors of the Bridgewater Treatises. Without going so far as this, we may well rejoice that he has in his own careful and exhaustive manner brought before us such an instance of adaptation as makes blind "selection" an impossibility, and forces us back on the old notion of One who has planned all things, and according to whose plan they are still working.

The book will also do good service in exposing the folly of that very superficial view which supposes that by evolution it is meant that all species are always in a state of change, every one working up to something, or sinking down to some lower grade if it proves unequal to the struggle. The true meaning of Darwinism is widely different from this: on that theory the struggle and change go on until a species has either disappeared or has established itself in surroundings suitable to its organisation: in this latter case it may go on unchanged for æons.* The earthworm, for instance, has got into the very place which suits it. It feeds underground, where eyes are useless, therefore it has no eyes; and hence the relatively vast amount of matter which passes through it compared with the nourishment extracted therefrom. It does not develope into anything else, nor has it changed at all since the oldest geological stratum in which it is found. Its labour supports itself; but it does much more; it helps in an altogether unexpected way to support man; and this fact is surely altogether irreconcilable with the theory of blind forces working without purpose or design.

But we must let Mr. Darwin speak for himself: "The share which worms have taken in the formation of the layer of vegetable mould which covers the land in every moderately humid country is the subject of the present volume." And he at once begins by deprecating the objection that the subject is an insignificant one. *De minimis lex non curat* is certainly not true of science; and Mr. Darwin's whole teaching gives proof of the great importance of "small agencies and their accumulated effects." Other writers have noticed the value to the geologist of this thin layer of finely-triturated vegetable mould; but most of

* See, however, an article entitled "Degeneration," which appeared in this Journal in July, 1881.

them, like Elie de Beaumont, have insisted on its permanence. Mr. Darwin shows that, on the contrary, its most striking feature is its being continually renewed: "its component particles in most cases removed at not a very slow rate, and replaced by others due to the disintegration of the underlying materials," the agents in this work being worms, through whose stomachs the particles are passed; so that, instead of being called vegetable it rather deserves to be styled animal mould.

Mr. Darwin's views, as is always the case, are the result of long and minute observation. He first attacked the subject in 1837, in a short paper "On the Formation of Mould," read before the Geological Society of London. His attention, he tells us, was first called to the subject by Mr. Wedgwood, of Maer Hall, in Staffordshire, who pointed out to him that the apparent sinking of burnt marl, cinders, &c., strewn over a meadow, is due to the large quantity of fine earth continually brought up to the surface by worms in the form of castings. These castings are sooner or later spread out, and cover up any object left on the surface.

This "singular theory" was commented on by foreign geologists; one of whom, M. d'Archiac, says it may be true of damp, low-lying meadows, but not of woods, upland pastures, and ploughed land. This objector (Mr. Darwin replies) must be arguing from inner consciousness, for it is just on elevated commons (M. d'Archiac's upland pastures) that, in England at least, worm-castings are most abundant; while in gardens, where the soil is worked much more than in ploughed fields, Von Hensen, the great authority as to the habits of worms, estimates their number as about twice as many as in corn-fields. There is only an apparent contradiction here—the worms seem most active on the commons, because all their castings are visible; in the loose soil of gardens they get lost amid cavities, or are deposited within their burrows. Other objections to the theory were *à priori;* Mr. Fish, for instance, in the *Gardener's Chronicle,* remarked, "Considering their weakness and their size, the work they are represented to have accomplished is stupendous,"—a remark which Mr. Darwin calls "an instance of that inability to sum up the effects of a continually recurring cause which has often retarded the progress of science."

But Mr. Darwin was not likely to rest satisfied with a few observations, partly made by others. He has, for

nearly fifty years, been watching and experimenting. In 1842 an old pasture-field was covered with a layer of broken chalk; in 1871, on a trench being dug, the chalk was seen as a distinct layer seven inches below the surface. A layer of coal-ashes, laid down at the same time, was found at the end of the twenty-nine years in two parallel layers, one seven, the other five and a half inches below the surface. A still more striking case was that of a field ploughed in 1841, and then harrowed and left to become pasture. It was so thickly covered with small and large flints (some half as large as a child's hand) as to be always called "the stony field." When Mr. Darwin's sons ran down it the stones clattered together. Mr. Darwin used to doubt whether he should live to see the larger flints covered with vegetable mould and turf. But after thirty years all the stones had so completely disappeared that a horse could gallop from end to end without striking a single stone with his shoes. "To any one who remembered the appearance of the field in 1842, the transformation was wonderful, and this was certainly the work of the worms. . . . The average rate of accumulation of the mould was only an inch in twelve years; but the rate must have been much slower at first, and afterwards considerably quicker." Sometimes the work is much more quickly done, the rate probably depending on the suitableness of the soil for worms to multiply in. Thus a case is quoted from *Nature* (November, 1877), where a layer of coal-ashes was buried to a depth of seven inches in eighteen years.

Everything, in fact, "works downwards" (as the farmers say), not by its own weight, but by the labour of multitudes of minute ploughmen. In this way, not only is an ever fresh supply of nourishment provided for the surface plants, but remains which would have been lost or destroyed have been preserved for the enlightenment of an age capable of appreciating them.

Of this we shall see many instances by-and-by; but we must first, following Mr. Darwin, learn something of the nature and habits of the creatures to whom such a great work in the economy of nature is attributed. Worms, then, are found everywhere, from Iceland to Kerguelen Land, though their activity is stopped by frost, and by dry heat. They exist in most kinds of soil, even in the black peat of bogs, though in it they are rare, and are wholly absent from the drier brown fibrous peat which is so valued by

gardeners. They are found on the tops of mountains, except where the subjacent rocks are so near the surface that they cannot burrow deep enough in winter to escape being frozen. They are still semi-aquatic (Mr. Darwin seems to think they are developed from a wholly aquatic ancestor); for though the dry air of a room is fatal to them in a single night, they have been kept alive for four months completely submerged in water. This is M. Perrier's experience, but no doubt Mr. Darwin has taken care to verify it abundantly; else it would seem to be contradicted by the fact, which must have struck most people, of the great number of dead worms almost always to be seen on the surface after heavy rain succeeding dry weather. These Mr. Darwin thinks were already sick; for the worm suffers from divers maladies, notably from the attacks of a parasitic fly, with which most of those that are found roaming about by daytime are affected. To move by day is contrary to the worm's habits; and the division between rest and activity has become so much a matter of habit that worms kept in pots in total darkness still went on working during the night, and resting by day.

Not that they are wholly insensible to light. Despite their blindness, a strong sudden light sends them back at once into their holes. Moderately radiant heat, diffused from "a poker heated to dull redness," does not produce so much effect as a bright light. The latter, of course, must act on the cerebral ganglia (for worms are furnished with such an apparatus) through the skin, the degree of extension and consequent transparency of which determines apparently the action of the light. When busily at work, worms are far less sensitive to light than at other times.

Each of the rings of which their bodies are made up is furnished with minute slightly reflexed bristles; by these they hold so fast to the inside of their burrows that they can seldom be dragged out without being torn in pieces. Between the crop and the intestines they have a gizzard, in which grains of sand and small stones from one-twentieth to one-tenth of an inch across are generally to be found. These serve like mill-stones to triturate their food. They can swallow without injury pointed bits of glass, and Mr. Darwin thinks that when wounded they feel far less pain than their contortions would lead us to imagine. Of hearing they have no organs of sense whatever. A bassoon at

its loudest affects them not at all, nor a whistle, nor a shout if care is taken that the breath does not strike them. For to vibrations they are very sensitive. Place a pot containing worms on a piano, and they at once retreat to their burrows the moment a note is struck. Their sense of smell seems developed with strange irregularity. To tobacco-juice, paraffin, and millefleurs Mr. Darwin found them insensible. But buried bits of onion and cabbage and of fresh raw meat were discovered, though in some cases very slowly. One bit of onion, for instance, was only found after three nights. With Mr. Darwin's usual care, *some of the buried objects were laid on tinfoil* so as to ascertain whether in any case they had been accidentally come upon by worms burrowing up from below.

It is strange to find worms so dainty that they can distinguish between different kinds of cabbage, preferring the green to the red, and so discriminating that they show a marked preference for that brain-feeding vegetable celery. The digestive value of prussic acid seems also to be appreciated, for "on many trials wild-cherry leaves were greatly preferred to those of lime or hazel." Their digestive fluid is said to be akin to the pancreatic secretion of the higher animals, and is used on the leaves which form so large a part of their food before they begin to eat them. This extra-stomachical digestion Mr. Darwin considers unique. The nearest analogy to it is found in the sun-dew (*drosera*) and other carnivorous plants, which convert animal matter into pepsine not in a stomach but on the surface of the leaves. Acidity, the natural result of eating quantities of half-decayed leaves, is combated by the calciferous glands which produce an alkaline reaction.

As a worm has a digestion, we shall not be astonished to find it gifted with mental powers. Laura Bridgman, though in her many of the ordinary avenues of intelligence were closed, was not unintelligent; why then should worms be, albeit deficient in several sense-organs? They have instincts, which are shown in the way they line their burrows with fine earth and sometimes with little stones, and plug the mouths of them with leaves; very young worms are found acting thus. But they have much more; and the chapter that Mr. Darwin devotes to establishing this point is perhaps the most interesting in the book. It is chiefly in the plugging of their burrows, he says, that

this intelligence is shown. A leaf may be either dragged in by the point or the foot-stalk or the middle; and the most careful experiments were conducted in order to ascertain which was the usual mode employed by worms, for, of course, if a man had to fill a small cylindrical hole he would drag or push in the leaves by their pointed ends, unless they were very thin relatively to the size of the hole, in which case he would probably insert some by their thicker or broader ends. Worms in this matter show themselves almost as sagacious as men. Leaves of rhododendrons and other foreign trees were tried, about which their ancestors knew nothing, and therefore instinct (*i.e.*, "an unvarying inherited impulse") could not help them; yet the percentage of those drawn in by the tip was vastly the greatest. This was not, however, invariably the case, as it would have been had the creatures worked solely through instinct. The numbers were in one case eighty per cent. by the tip, nine by the base, eleven by the middle; in another sixty-three per cent. by the tip, twenty-seven by the base, ten by the middle (in this case the leaf was laburnum, specially narrow at the base). Some rhododendrons are smallest towards the base; and of these sixty-six per cent. had been drawn in by the base, and only twenty-four by the tip. In fact the worms were found to judge with a considerable degree of correctness which was the readiest mode of procedure. The leaves of pines consist of two needles united at a common base; these were almost always drawn in by the base, not, however, because the two divergent needles were hard to manage, for when these were waxed together, or bound together with thread, the worms almost uniformly went on pulling by the bases as before. Pine leaves are not natives of the south of England, therefore the habit of burying them could not be an inherited one; neither was it confined to worms brought up under their shadow, for such leaves were laid on the ground in places where pine trees had never grown. The base of a pine leaf seems therefore to afford something attractive to worms in the way of nutriment, since these leaves are so much more frequently drawn in by the foot-stalk than others. With the foot-stalks of compound leaves, like the ash or the robinia, both methods obtain. The number of those drawn in by the tip, after the leaflets had fallen off, was very much larger than of those drawn in by the base, except in the case of

the ash, of which the worms are very fond, and which they clearly draw in by the thick end for use as food. To decide between this somewhat conflicting evidence Mr. Darwin was at the pains to cut triangles out of moderately stiff writing paper, with sides three inches long and bases an inch long in 120 cases, and half an inch in 183 cases. These were rubbed with raw fat on both sides to prevent dew and rain from making them excessively limp; and similar triangles, damped, were drawn in all sorts of different ways into a tube of the width of a worm-burrow. "Now if," argues Mr. Darwin, "worms seized indifferently by chance any part, they would assuredly seize on the basal part far oftener than on either of the two other divisions; for the area of the basal to the apical part is five to one, if the triangle be divided into three parts by lines an inch asunder parallel to the base." On the contrary it was found that, of 303 triangles experimented on, sixty-two per cent. were seized by or near the apex, fifteen by the middle, twenty-three by the basal part. "We may conclude, therefore, that the manner in which the triangles are drawn into the burrows is not a matter of chance."

It was clear, moreover, that the worms had not selected the apex as most convenient after having tried other ways and failed, *for the bases of the triangles drawn in by the apex were clean and not crumpled:* "we may therefore infer, improbable as is the inference, that worms are able by some means to judge which is the best end by which to draw paper triangles into their burrows." A still higher percentage than that of the triangles was reached in the case of lime-tree leaves (very broad at the base), of which seventy-nine per cent. were dragged in by the apex and only four by the base. Chance, then, is excluded; and inherited habit, which so often simulates intelligence, could not have been acquired in reference to objects, like paper triangles or foreign plants, wholly unknown to the progenitors of the worms experimented upon; and it does not appear (from the cleanness of the bases of the triangles) that the worms often try first in one way and then in another, though, if they did, they would be profiting by experience in a way in which many higher animals are wholly unable to profit by it. The conclusion therefore remains that they are able *to acquire some notion* of the general shape of an object, probably by touch, as

those who are born blind and deaf do. "And if worms have this power, even in a slight degree, they deserve to be called intelligent; for they then act in nearly the "same manner as a man would under similar circumstances." If this, adds our author, seems an unlikely supposition, we must remember how little we know of the nervous system of the lower animals, and what a mass of inherited knowledge, with some power of adapting means to ends, is crowded into the minute brain of a worker-ant, and yet an ant is often seen trying to drag an object transversely which could more easily be drawn longitudinally.

It was necessary to glorify the creature to which is assigned such an important part in the preparation of the soil. The worm has an amount of intelligence that may well put to shame the weaver-bird which keeps on winding threads through the bars of its cage as if building a nest, and the beaver which cuts up logs and drags them about even where there is no water to dam up, and many other creatures, far higher in the scale than itself, which yet follow instinct in a blind and purposeless way. The worm has a purpose in what it does.

That earth is swallowed for food, and not merely in making the burrows, is next proved. Mr. Darwin has even watched the worms at work making their casts; and he speaks of "tower-like castings, some three inches high," photographed by Dr. King, at Nice, and others, still higher, from Bengal and the Neilgherries; and then comes the most important item in the many calculations so carefully and minutely made, viz., the amount of earth brought by worms to the surface, and afterwards spread out by rain and wind. This was judged of by two methods: by the rate at which surface objects are buried, and by weighing the quantity brought up in a given time. We have already spoken of the first method, which has been pursued both near Maer Hall, and also near Mr. Darwin's house in Kent. Cases are given of great stones undermined by worms, and in this way half buried; while if they are of such huge dimensions that the earth beneath is kept dry, and therefore not inhabited by worms, they do not sink at all. In this way the fallen stones at Stonehenge have been buried to a depth of about nine and a half inches; but since it is uncertain when they fell, no calculation can in this case be made of the rate of growth of the vegetable mould. The rate of sinking does not appear to depend on

the weight of the objects, porous cinders are covered as deep as ponderous flints.

The weight of earth brought up by worms will of course depend on the number of worms in a given area. These are far more numerous than we should fancy. Von Hensen calculates, we are not told on what data, nearly 54,000 in an acre of *garden* ground. Pour vinegar, or water in which walnut shells have been steeped, on a patch of ground, and you will be astonished at the multitude of worms that come up to die. As to the castings, they are far the heaviest on very poor English pasture, the next heaviest being those on the Neilgherries. Their amount varies from eighteen tons to fourteen and a half tons per acre in low-lying fields in the chalk, to from sixteen to seven tons in chalk hills.

The part which worms have played in burying old buildings is set forth in the case of the Roman villas at Abinger and Brading. Here not only are the beautifully tesselated pavements covered to a depth of several inches, but the very walls of houses, &c., have in many cases been undermined. Sometimes the tesselated pavement has sunk in the centre, the edges having been kept up by adhering to the walls. It is strange to think of worms making their way through the concrete underlying Roman pavements, and then passing up between the tesseræ; but this is undoubtedly the fact, as is proved by observations made at Abinger during the three autumn months of 1877 on the floor of the atrium, which has subsided, while still keeping pretty level, owing to the collapsing of the worm-burrows in the soil beneath it. The depth of the overlying mould in this villa was in some places sixteen inches, which had been deposited in the course of some fourteen or fifteen hundred years. In Beaulieu Abbey, the tesselated pavement discovered in 1853 lay at depths varying from six and three-quarters to eleven and a half inches below the turf. This abbey was wholly destroyed by Henry VIII., so that the time the worms have been at work can be pretty accurately fixed. Of course, the rate of deposit in such cases is much slower than that on ordinary land; and it seems as if Mr. Darwin ought to explain why such floorings are not always left as hollows in the surface (as they are in many cases), seeing that the soil outside them is much more rapidly raised than that which has to be brought up from below them. The villa at Brading, discovered last

October, is on a very grand scale, no less than eighteen rooms having been opened. Here the mould and rubbish was from three to four feet thick in the rooms, the thickness on the broken walls varying from four to eighteen inches. At Chadworth, in Gloucestershire, the depth of mould over a very fine tesselated pavement was twenty-six inches. Of the work at Silchester, Hants, undertaken by Rev. J. G. Joyce for the Duke of Wellington, Mr. Darwin gives a very long account. Here the depth of mould varied with the slope of the ground from twenty-nine to eleven and a half inches. At Wroxeter the mould in some parts reached a thickness of forty inches.

On the whole, then, worms have played a large part in covering up and concealing ancient buildings; they have played a much more important part in that denudation that has gradually changed the crystalline rocks of which the earth was originally composed into existing strata. The help worms give in this work is mainly by preventing such an accumulation of mould as would hinder any change from taking place in the underlying rocks. The mould triturated and brought to the surface by the worms is washed down by rains, and so the underlying rock becomes subject to atmospheric changes, and to the action of humus-acids. And these humus-acids, which are so powerful in disintegrating rocks, are generated within the bodies of worms during the digestive process. But, besides this indirect chemical work, Mr. Darwin is persuaded that they act directly and mechanically on the smaller particles of rock. We can well believe this when we learn that some genera have two gizzards, and one genus (*moniligaster*) has five. And their numbers are such that in Great Britain, reckoning only the land which is cultivated and fitted for their working, viz., thirty-two million acres, the amount of soil that passes yearly through their bodies is 320 million tons. It is startling to think how much this must have been in a single geological period, of many thousand years. And of this prepared mould a surprising weight is constantly being washed down from hill-sides. For every 100 yards of a valley with sides sloping at an angle of 9° 26′, 480 cubic inches of damp earth weighing above 23 lbs. will annually reach the bottom. The ledges, so constantly found on the hill-sides and the sides of chalk downs, and usually supposed to be sheep-runs, Mr. Darwin believes to be due in some cases to the accumulation of disinte-

grated and rolled worm-castings arrested in their descent by some irregularity in the surface. Sir J. Hooker noticed them in the Himalayas and the Atlas, where there are no domestic animals and few wild ones; and Dr. King saw them in the act of formation in the Corniche. Worm-castings, too, when dry, are carried in considerable quantities in the shape of dust. This displacement produces a sensible effect in some countries. In England Mr. Darwin thinks it is not dry, but moist, recently-ejected castings which are as a rule displaced, being driven in a north-easterly direction by the strong, rainy, south-westerly gales. His son Horace probed the shallow circular trenches near Stonehenge, said to be contemporaneous with the Druidical stones, and found that on the whole the mould due to the action of worms was much thicker on the north-east than on the other parts of the circles. As an instance of the careful tenacity with which even the minutest question is investigated, we may take the following:

"Several old castings on my lawn were marked with pins, and protected from any disturbance. They were examined after an interval of ten weeks, during which the weather had been alternately dry and rainy. Some which were of a yellowish colour had been washed away almost completely, as could be seen by the colour of the surrounding ground. Others had completely disappeared, and these no doubt had been blown away. Lastly, others still remained, and would long remain, as blades of grass had grown through them."

And again:

"Eight castings were found on my lawn, where the grass-blades are fine and close together, and three others on a field with coarse grass. The inclination of the surface at the eleven places where these castings were collected varied between 4° 30′ and 17° 30′; the mean of the eleven inclinations being 9° 26′. The length of the castings in the direction of the slope was first measured with as much accuracy as their irregularities would permit. It was found possible to make these measurements within about one-eighth of an inch, but one of the castings was too irregular to admit of measurement. The average length in the direction of the slope of the remaining ten castings was 2·03 inches. The castings were then divided with a knife into two parts along a horizontal line passing through the mouth of the burrows, which was discovered by slicing off the turf; and all the ejected earth was separately collected, namely, the part above the hole and the part below. Afterwards these two parts were weighed. In every

case there was much more earth below than above; the mean weight of that above being 103 grains, and of that below 205 grains; so that the latter was very nearly double the former. As on level ground castings are commonly thrown up almost equally round the mouths of the burrows, this difference in weight indicates the amount of ejected earth which had flowed down the slope. But very many more observations would be requisite to arrive at any general results; for the nature of the vegetation and other accidental circumstances, such as the heaviness of the rain, the direction and force of the wind, &c., appear to be more important in determining the quantity of the earth which flows down a slope than its angle. Thus with four castings on my lawn (included in the above eleven) where the mean slope was 7° 19′, the difference in the amount of earth above and below the burrows was greater than with three other castings on the same lawn where the mean slope was 12° 5′."

In another instance Mr. Darwin covers some of the worm-casts on his lawn with powdered chalk, so as to judge of the denuding effect of rains. Indeed the two chapters on denudation are throughout a wonderful instance of patient research and close reasoning. At times we feel disposed to sit in the seat of the scornful, and to liken all this weighing of worm-earths, this measuring their angles and heights, to the way in which, according to Aristophanes in the *Clouds*, Socrates and his pupils used to study physics. To take in wax the print of a flea's foot and so to ascertain how many of its own paces it takes when it makes a leap is not, at first sight, very different from Mr. Darwin's methods with worms. The difference is, that the one belongs to the fruitful, the other to the barren class of experiments, according to the Baconian division. Mr. Darwin traces a continuous connection between the facts which he adduces and the theory which he bases on them; and, if the basis sometimes seems small to support such a superstructure, we must not forget his reminder of the composite effect of a very minute cause indefinitely multiplied.

One thing strikes us, and not for the first time—the way in which Mr. Darwin is helped by his sons. One or other of the three is mentioned in almost every other page as a careful fellow-worker whose observations are to the full as trustworthy as his father's. It is no slight thing to have impressed his own household with the importance of a kind of work which, to so many young people, would seem like solemn trifling. It is not often that heredity shows

itself so strongly as in the Darwin family. Dr. Darwin, a close observer for the times when he lived, was so far on the road to evolution that carping critics have accused our author of plagiarism, for not having more distinctly acknowledged his obligation to his relative. The elder Darwin, indeed, was less blessed with help in his own family; his eldest son, we remember, fell a victim to an insanity from which the collateral branches are wholly free; but his geniality was shown by the remarkable way in which he attached to himself a circle of friends; and the way in which the experiments recorded in this volume have been made quite a family work, shows that the geniality is hereditary.

This tone of geniality makes us all the more regret that, while assigning to worms a certain amount of intelligence, and a wholly unsuspected share in the economy of nature, Mr. Darwin has not been able to speak out, and to tell his readers that, if common sense is to be of any value in the argument, an intelligent worm filling no insignificant place in the work of fitting the world for man is a wholly incomprehensible phenomenon, apart from an intelligent plan designed by an intelligent Creator. We wish he had said something of this kind in his concluding chapter.

In that chapter, he gives us the experiment of Von Hensen, showing the rapidity with which worms manufacture the black vegetable mould which is so largely their work. Two worms were placed in a vessel, eighteen inches wide, filled with sand. On this fallen leaves were strewn, and were soon dragged in to a depth of three inches.* After about six weeks an almost uniform layer of sand, nearly half an inch thick, had been turned into *humus* by having passed through the stomachs of the two worms, and having been there mingled with the refuse of the leaves. The worm does his work of commingling and pulverising far better than a gardener preparing a compost. Soil thus prepared is well fitted to retain moisture, and to absorb all soluble substances, and ladies may well find consolation for the occasional mischief done by worms to flower roots in the thought that the good they do in enriching and preparing the soil far outweighs any such harm.

In this way, then, adding fact to fact, and modifying his

* The rate of work is remarkable; for Mr. Darwin notes that worms in captivity are often idle, and work carelessly, owing perhaps to the dryness of the air in which they are placed.

views as new facts arise, Mr. Darwin arrives at the conclusion that worms at any rate are not useless creatures. Rather, they give one of the strongest proofs of the truth of that good old saying, There is no waste in nature; they show, too, that nature never puts forth unnecessary strength, but rather rejoices to work mighty results through seemingly insignificant causes. If the *Descent of Man* was something like a dethroning of humanity from its immemorial seat, surely this is lifting these humble and often despised creatures to an undreamt-of importance. This is how Mr. Darwin sums up the case:

"Worms have played a more important part in the history of the world than most persons would at first suppose. In almost all humid countries they are extraordinarily numerous, and for their size possess great muscular power. In many parts of England a weight of more than ten tons (10,516 kilogrammes) of dry earth annually passes through their bodies, and is brought to the surface, on each acre of land; so that the whole superficial bed of vegetable mould passes through their bodies in the course of every few years. From the collapsing of the old burrows the mould is in constant though slow movement, and the particles composing it are thus rubbed together. By these means fresh surfaces are continually exposed to the action of the carbonic acid in the soil, and of the humus-acids which appear to be still more efficient in the decomposition of rocks. The generation of the humus-acid is probably hastened during the digestion of the many half-decayed leaves which worms consume. Thus the particles of earth forming the superficial mould are subjected to conditions eminently favourable for their decomposition and disintegration. Moreover, the particles of the softer rocks suffer some amount of mechanical trituration in the muscular gizzards of worms, in which small stones serve as mill-stones. . . . . When we behold a wide, turf-covered expanse, we should remember that its smoothness, on which so much of its beauty depends, is mainly due to all the inequalities having been slowly levelled by worms. It is a marvellous reflection that the whole of the superficial mould over any such expanse has passed, and will again pass, every few 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 existed the land was, in fact, regularly ploughed, and still continues to be thus ploughed by earthworms. 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."

Certainly their habits have never been so long and so

closely watched before, and Mr. Darwin has the credit of discovering many new facts in worm-life; that they can even eat concrete and bore through tesselated pavements was known before, but we are not aware that any one had pointed out the way in which they line their burrows, not only with humus but also in the upper part with leaves, filling up the interstices with small stones, beads, and such other things as have been scattered near. And in this, as in all other cases, the more we get to close quarters with nature the more we are astonished at the unvarying adaptation of means to ends. Verily, as we said, Mr. Darwin deserves a share of the credit bestowed on the Duke of Bridgewater's treatise-writers, in spite of his having declined to push his inferences to their just conclusions.

Worms, he shows, have chiefly formed that surface soil on which the fertility of our globe depends. They are continually renewing it, and (helped by rain and wind) equalising its distribution. And they do this at a great sacrifice to themselves. For earth is not their favourite food,* but celery, onion, cabbage, and, above all, raw fat meat. The dungheap suits them much better than the chalk down. Why should they not, on the principle that each creature chooses for itself its most suitable surroundings, have sought the former and disappeared from the latter? It would almost seem as if a worm, living in hungry land of which it has to pass a vast quantity through its intestines, in order to extract a very small amount of nourishment, in contradiction to the laureate's dictum, that no creature "but subserves another's end," is clearly not doing the best for itself, but doing its share towards carrying on the designs of Providence.

We cannot believe but that its author meant something of this kind by the passage just quoted, and the book before us is therefore not only of great interest in itself, as everything that Mr. Darwin writes must be, but also because it seems to be conceived in a somewhat different spirit from those earlier works on which atheists as well as agnostics seized as if of right.

Mr. Darwin says nothing of conscious design; but he puts wholly in the background all that machinery of happy accidents which hasty readers persisted in identifying with

* Average English earth contains less than 2 per cent. of organic matter; the black earth of South Russia has 12 per cent.

the old "fortuitous concourse of atoms." There is nothing in this volume like the explanation, which some of our readers will remember, how it comes to pass that the European cuckoo lays its eggs in another bird's nest while the cuckoo of America builds a nest of its own. It is the result, we are told, of an accident. Suppose the cuckoo happened to lay its eggs in another nest; well, if some benefit accrued therefrom either to the parent bird or to its young—if the cuckoo-chick throve better owing to the unconscious care of its adopted mother, it is easy to see how an accident may have become *a habit advantageous to the species;* for all analogy leads us to believe that the bird thus reared would partly at least inherit the deviation of instinct which led its mother to abandon it. The strongest cuckoos being those that were reared in other birds' nests, the race of cuckoos would become more and more given to this abnormal kind of egg-laying. This very startling way of building on assumptions is thoroughly disposed of by M. Paul Janet in a remarkable paper on "The Materialism of the Day" in the *Revue des Deux Mondes* for 1st Dec., 1863, who cites the case of the *pompilia*—insects which lay their eggs in dead animals, that their larvæ may find suitable nourishment ready to hand. The difficulty here is that while the larvæ are carnivorous, the insects themselves feed on vegetables; and M. Janet insists that it is a difficulty which natural selection cannot pretend to solve, for it is not a case of thriving better on one kind of food than on another. It is a trial of faith to imagine that larvæ, originally herbivorous, came all at once to be carnivorous through the accident of their eggs having been laid in or near a dead body, and that, thriving on this wholly new food, they transmitted this new habit, which had proved to be advantageous, through the larva state to the complete insect. Such cases as these we see at once are based on gratuitous assumptions—demand vastly more faith than is claimed by those who would have us believe in the literal rendering of every word in Gen. i. We are glad that, as we said, this book is free from them.

As for the general argument from design, we are not among those who think that Paley is out of date. It has been the custom for more than a generation to sneer at his once-famous passage about the man who found a watch on an uninhabited island, and thence concluded that some human being must have been there before him; and to say,

that is all very well in the case of watches, for we know all about the making of them, and to connect a watch with a watchmaker is the result of experience; whereas we know nothing of how worlds are made, and whether in their case a maker is absolutely indispensable. In his former works, notably in the *Origin of Species*, Mr. Darwin's reticence allowed unbelievers to rush eagerly upon his facts, and to cry out that "natural selection" was the working of blind, aimless chance, forgetting the radical difference between artificial selection and the working of such a blind power. Man, as has so often been pointed out, obtains certain results by working with a special object, *i.e.*, with design: he chooses and combines with a view to the desired end. When we study the similar selective work of nature, surely it is gratuitously illogical to insist that this must be the work of chance. One thing cannot be too often borne in mind: the more complicated our arrangement is, the more numerous the elements that enter into it, the more unlikely it becomes that it can be the result of chance. You throw three dominoes, and it is not impossible that they should in falling range themselves in the form of an equilateral triangle; but, if you throw a hundred, the chances against their forming any regular geometrical figure are almost innumerable.

An evolutionist theist, an evolutionist pantheist, are readily conceivable; though the distinction between the two is futile, for nature becomes God to one who believes that all matter is instinct with a self-regulating power; but an evolutionist atheist passes our understanding. We can fancy Mr. Darwin smiling sorrowfully at the use many have made of his facts and his theories. We can almost imagine his having put forth the present book as evidence of how much he has been misunderstood. However this may be, we are confident that it will do good. Sure to be largely read, clear even beyond its author's usual clearness, with scarcely a scientific word from beginning to end, and containing in our opinion the clearest evidences of design, it is well fitted to counteract the theories which have (wrongly but persistently) been coupled with the name of Darwin.

People are only now beginning to understand Mr. Darwin's drift. At first, his views were identified with those of Lamarck, that the need for a new organ is sufficient to produce it—that after wishing, through long generations,

to find some readier means than its fins afforded of escaping its enemies, a fish would develope rudiments of wings which, by dint of use, would become strong and serviceable. Cuvier showed the absurdity of thus imagining living organisms, to be "*comme une simple moule de pâte ou d'argile qui se laisserait mouler entre les doigts.*" Even at this distance of time the passage in the *Anatomie Comparée* (p. 100) is well worth reading. It is an answer, not to Darwinism, but to those views which have been falsely coupled with the name, and which (says the great Frenchman) betray a total ignorance of anatomy.

We hope the present volume will put an end to the misapprehension which has allowed our foremost observer to be claimed by theorising atheists; and we hope that before long one who is so justly valued as a careful recorder of facts will recognise the inference to which these facts lead up.

We cannot think that one who has proved so clearly, and by such a multitude of minute experiments, what worms do, and how little proportionate advantage they get from their doing it, should be able to avoid the, to us, inevitable conclusion, that there is conscious design in the part assigned to these humble creatures. Finally, we ask no one to form conclusions on the book till he has read and studied it as a whole. Such a careful study is specially needed for the chapters on denudation. Sometimes in these chapters we might at first think Mr. Darwin was begging the question, at other times we might think his grounds insufficient. For instance, when, having measured and weighed the degradation of the worm-casts on sloping ground, he adds: "As on level ground castings are *commonly thrown up almost equally* round the mouths of the burrows; this difference in weight indicates the amount of ejected earth which had flowed down the slope." In an ordinary writer the words we have italicised might mean anything or nothing; coming from Mr. Darwin we may be sure they are sufficient, and if we read further on we shall find that they are not exclusively relied on. Mr. Darwin never rests an argument on a single set of facts.

The book, then, is in many ways interesting, chiefly, from our point of view, as an unexpected instance of the way in which Thought governs the universe. We can see no alternative between the doctrine of a Providence and that of mechanical fatalism. The conception of a blind will aim-

ing at it knows not what, and working up to that unconsciously, is one of the wildest that even a German brain ever formed. That thought may reach its aim it must know what it aims at. Not only do—

> "All things hold their march
> As if by one great Will,"

But that Will is a reality; there is no "as if" about it. The whole universe is working up to that perfect ideal which has always been present in the mind of God. A non-existent ideal is but a poor object to aim at. The ideal, the end, must be, and must be known to Him in whom all things live, and move, and have their being. In no other way can we conceive of the two series—of cause and effect and means and ends—as fairly reconciled. How can this mechanism of nature, the beautiful arrangement of which is conspicuously shown forth in the work that the earthworm has been doing, not for itself alone, for uncounted ages, be carried out to that perfection which alone can satisfy even the mind of man? How can the ascending and descending scales—cause below cause till we lose ourselves in the infinitely little, and end above end till we rise to the infinitely great—be harmoniously linked together? Only by the certainty that Thought first chose the way in which things should move, and guided them along that way; and that Will, in a manner past our comprehension, keeps them in the way wherein they should go.

We could not expect Mr. Darwin to say all this; his aim is to collect and group facts, and to draw from them their immediate conclusions; but we are thankful that there is nothing in his last book which contravenes the idea of an intelligent will, guiding all things to a preordained end, and that, on the contrary, there is a great deal from which it may be inferred, and which, further still, seems to make any other hypothesis untenable.