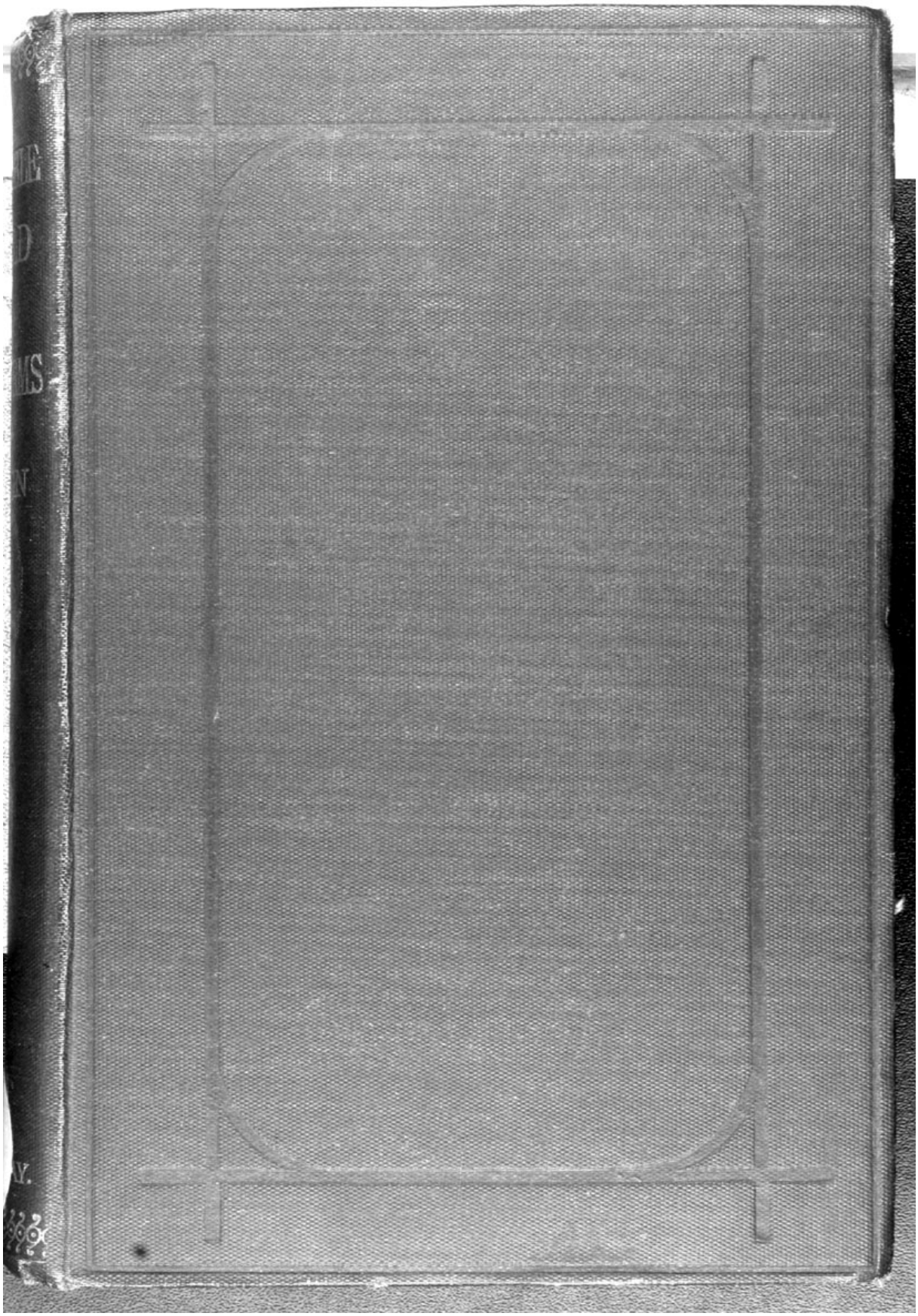
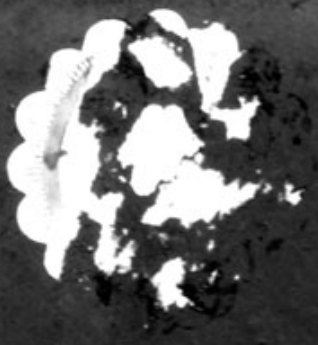
The formation of vegetable mould, through the action of worms

Charles Darwin





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.

FIFTH THOUSAND (CORRECTED).

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1881.

LONDON:
PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
STAMFORD STREET AND CHARING CROSS.

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founded on the numbers found in a garden, and Hensen believes that worms are here twice as numerous as in corn-fields. The above result, astonishing though it be, seems to me credible, judging from the number of worms which I have sometimes seen, and from the number daily destroyed by birds without the species being exterminated. Some barrels of bad ale were left on Mr. Miller's land,* in the hope of making vinegar, but the vinegar proved bad, and the barrels were upset. It should be premised that acetic acid is so deadly a poison to worms that Perrier found that a glass rod dipped into this acid and then into a considerable body of water in which worms were immersed, invariably killed them quickly. On the morning after the barrels had been upset, "the "heaps of worms which lay dead on the "ground were so amazing, that if Mr. Miller "had not seen them, he could not have "thought it possible for such numbers to "have existed in the space." As further evidence of the large number of worms which live in the ground, Hensen states that he

* See Mr. Dancer's paper in 'Proc. Phil. Soc. of Manchester,' 1877, p. 248.

found in a garden sixty-four open burrows in a space of 14½ square feet, that is, nine in 2 square feet. But the burrows are sometimes much more numerous, for when digging in a grass-field near Maer Hall, I found a cake of dry earth, as large as my two open hands, which was penetrated by seven burrows, as large as goose-quills.

Weight of the earth ejected from a single burrow, and from all the burrows within a given space.—With respect to the weight of the earth daily ejected by worms, Hensen found that it amounted, in the case of some worms which he kept in confinement, and which he appears to have fed with leaves, to only 0·5 gram, or less than 8 grains per diem. But a very much larger amount must be ejected by worms in their natural state, at the periods when they consume earth as food instead of leaves, and when they are making deep burrows. This is rendered almost certain by the following weights of the castings thrown up at the mouths of single burrows; the whole of which appeared to have been ejected within no long time, as was certainly the case in several instances. The

castings were dried (excepting in one specified instance) by exposure during many days to the sun or before a hot fire.

WEIGHT OF THE CASTINGS ACCUMULATED AT THE MOUTH OF A SINGLE BURROW.

	Ounces.
(1.) Down, Kent (sub-soil red clay, full of flints, overlying the chalk). The largest casting which I could find on the flanks of a steep valley, the sub-soil being here shallow. In this one case, the casting was not well dried	3·98
(2.) Down.—Largest casting which I could find (consisting chiefly of calcareous matter), on extremely poor pasture land at the bottom of the valley mentioned under (1.)	3·87
(3.) Down.—A large casting, but not of unusual size, from a nearly level field, poor pasture, laid down in grass about 35 years before	1·22
(4.) Down.—Average weight of 11 not large castings ejected on a sloping surface on my lawn, after they had suffered some loss of weight from being exposed during a considerable length of time to rain ..	0·7
(5.) Near Nice in France.—Average weight of 12 castings of ordinary dimensions, collected by Dr. King on land which had not been mown for a long time and where worms abounded, viz., a lawn protected by shrubberies, near the sea; soil sandy and calcareous; these castings had been exposed for some time to rain, before being collected, and must have lost some weight by disintegration, but they still retained their form	1·37
(6.) The heaviest of the above twelve castings ..	1·76
(7.) Lower Bengal.—Average weight of 22 castings, collected by Mr. J. Scott, and stated by him to have been thrown up in the course of one or two nights	1·24
(8.) The heaviest of the above 22 castings	2·09
(9.) Nilgiri Mountains, S. India; average weight of the 5 largest castings collected by Dr. King. They had been exposed to the rain of the last monsoon, and must have lost some weight	3·15
(10.) The heaviest of the above 5 castings	4·34

In this table we see that castings which had

been ejected at the mouth of the same burrow, and which in most cases appeared fresh and always retained their vermiform configuration, generally exceeded an ounce in weight after being dried, and sometimes nearly equalled a quarter of a pound. On the Nilgiri mountains one casting even exceeded this latter weight. The largest castings in England were found on extremely poor pasture-land; and these, as far as I have seen, are generally larger than those on land producing a rich vegetation. It would appear that worms have to swallow a greater amount of earth on poor than on rich land, in order to obtain sufficient nutriment.

With respect to the tower-like castings near Nice (Nos. 5 and 6 in the above table), Dr. King often found five or six of them on a square foot of surface; and these, judging from their average weight, would have weighed together $7\frac{1}{2}$ ounces; so that the weight of those on a square yard would have been 4 lb. $3\frac{1}{2}$ oz. Dr. King collected, near the close of the year 1872, all the castings which still retained their vermiform shape, whether broken down or not, from a

square foot, in a place abounding with worms, on the summit of a bank, where no castings could have rolled down from above. These castings must have been ejected, as he judged from their appearance in reference to the rainy and dry periods near Nice, within the previous five or six months; they weighed $9\frac{1}{2}$ oz., or 5 lb. $5\frac{1}{2}$ oz. per square yard. After an interval of four months, Dr. King collected all the castings subsequently ejected on the same square foot of surface, and they weighed $2\frac{1}{2}$ oz., or 1 lb. $6\frac{1}{2}$ oz. per square yard. Therefore within about ten months, or we will say for safety's sake within a year, 12 oz. of castings were thrown up on this one square foot, or 6·75 pounds on the square yard; and this would give 14·58 tons per acre.

In a field at the bottom of a valley in the chalk (see No. 2 in the foregoing table), a square yard was measured at a spot where very large castings abounded; they appeared, however, almost equally numerous in a few other places. These castings, which retained perfectly their vermiform shape, were collected; and they weighed when partially dried, 1 lb. $13\frac{1}{2}$ oz. This field had been

rolled with a heavy agricultural roller fifty-two days before, and this would certainly have flattened every single casting on the land. The weather had been very dry for two or three weeks before the day of collection, so that not one casting appeared fresh or had been recently ejected. We may therefore assume that those which were weighed had been ejected within, we will say, forty days from the time when the field was rolled,—that is, twelve days short of the whole intervening period. I had examined the same part of the field shortly before it was rolled, and it then abounded with fresh castings. Worms do not work in dry weather during the summer, or in winter during severe frosts. If we assume that they work for only half the year—though this is too low an estimate—then the worms in this field would eject during the year, 8·387 pounds per square yard; or 18·12 tons per acre, assuming the whole surface to be equally productive in castings.

In the foregoing cases some of the necessary data had to be estimated, but in the two following cases the results are much more trustworthy. A lady, on whose ac-

curacy I can implicitly rely, offered to collect during a year all the castings thrown up on two separate square yards, near Leith Hill Place, in Surrey. The amount collected was, however, somewhat less than that originally ejected by the worms; for, as I have repeatedly observed, a good deal of the finest earth is washed away, whenever castings are thrown up during or shortly before heavy rain. Small portions also adhered to the surrounding blades of grass, and it required too much time to detach every one of them. On sandy soil, as in the present instance, castings are liable to crumble after dry weather, and particles were thus often lost. The lady also occasionally left home for a week or two, and at such times the castings must have suffered still greater loss from exposure to the weather. These losses were, however, compensated to some extent by the collections having been made on one of the squares for four days, and on the other square for two days more than the year.

A space was selected (October 9th, 1870) on a broad, grass-covered terrace, which had been mowed and swept during many years. It faced the south, but was shaded during

part of the day by trees. It had been formed at least a century ago by a great accumulation of small and large fragments of sandstone, together with some sandy earth, rammed down level. It is probable that it was at first protected by being covered with turf. This terrace, judging from the number of castings on it, was rather unfavourable for the existence of worms, in comparison with the neighbouring fields and an upper terrace. It was indeed surprising that as many worms could live here as were seen; for on digging a hole in this terrace, the black vegetable mould together with the turf was only four inches in thickness, beneath which lay the level surface of light-coloured sandy soil, with many fragments of sandstone. Before any castings were collected all the previously existing ones were carefully removed. The last day's collection was on October 14th, 1871. The castings were then well dried before a fire; and they weighed exactly $3\frac{1}{2}$ lbs. This would give for an acre of similar land 7·56 tons of dry earth annually ejected by worms.

The second square was marked on un-

enclosed common land, at a height of about 700 ft. above the sea, at some little distance from Leith Hill Tower. The surface was clothed with short, fine turf, and had never been disturbed by the hand of man. The spot selected appeared neither particularly favourable nor the reverse for worms; but I have often noticed that castings are especially abundant on common land, and this may, perhaps, be attributed to the poorness of the soil. The vegetable mould was here between three and four inches in thickness. As this spot was at some distance from the house where the lady lived, the castings were not collected at such short intervals of time as those on the terrace; consequently the loss of fine earth during rainy weather must have been greater in this than in the last case. The castings moreover were more sandy, and in collecting them during dry weather they sometimes crumbled into dust, and much was thus lost. Therefore it is certain that the worms brought up to the surface considerably more earth than that which was collected. The last collection was made on October 27th, 1871; i.e., 367

days after the square had been marked out and the surface cleared of all pre-existing castings. The collected castings, after being well dried, weighed 7·453 pounds; and this would give, for an acre of the same kind of land, 16·1 tons of annually ejected dry earth.

SUMMARY OF THE FOUR FOREGOING CASES.

(1.) Castings ejected near Nice within about a year, collected by Dr. King on a square foot of surface, calculated to yield per acre 14·58 tons.

(2.) Castings ejected during about 45 days on a square yard, in a field of poor pasture at the bottom of a large valley in the Chalk, calculated to yield annually per acre 18·12 tons.

(3.) Castings collected from a square yard on an old terrace at Leith Hill Place, during 369 days, calculated to yield annually per acre 7·56 tons.

(4.) Castings collected from a square yard on Leith Hill Common during 367 days, calculated to yield annually per acre 16·1 tons.

The thickness of the layer of mould, which castings ejected during a year would form if uniformly spread out.—As we know from the two last cases in the above summary, the weight of the dried castings ejected by worms during a year on a square yard of surface, I wished to learn how thick a layer of ordinary mould this amount would form if spread uniformly over a square yard. The dry castings