

- Beispielhafter Auszug aus der digitalisierten Fassung im Format PDF -

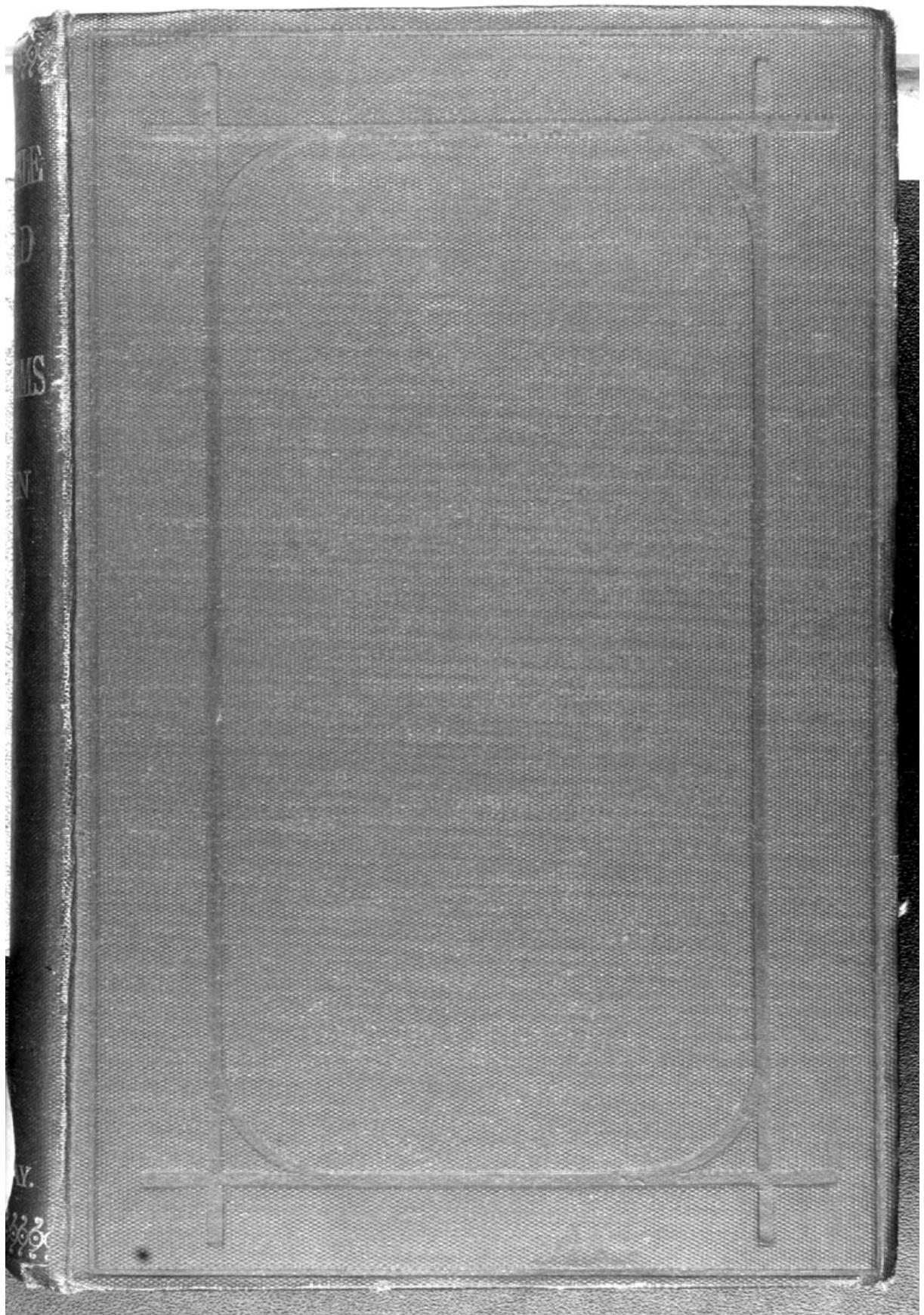
# The formation of vegetable mould, through the action of worms

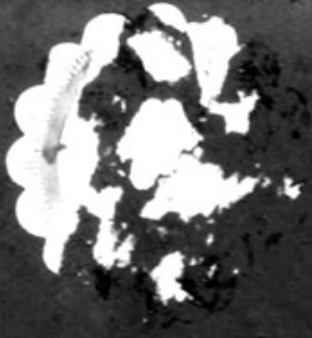
---

Charles Darwin

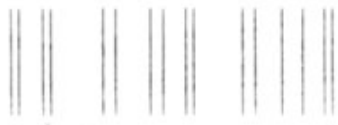
Die Digitalisierung dieses Werkes erfolgte im Rahmen des Projektes BioLib ([www.BioLib.de](http://www.BioLib.de)).

Die Bilddateien wurden im Rahmen des Projektes Virtuelle Fachbibliothek Biologie (ViFaBio) durch die [Universitätsbibliothek Johann Christian Senckenberg \(Frankfurt am Main\)](#) in das Format PDF überführt, archiviert und zugänglich gemacht.





Tc40/2



T040  
2

(T109)

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.

*The right of Translation is reserved.*

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

# CONTENTS.



INTRODUCTION . . . . . Page 1-7

## CHAPTER I.

### HABITS OF WORMS.

Nature of the sites inhabited—Can live long under water—Nocturnal—Wander about at night—Often lie close to the mouths of their burrows, and are thus destroyed in large numbers by birds—Structure—Do not possess eyes, but can distinguish between light and darkness—Retreat rapidly when brightly illuminated, not by a reflex action—Power of attention—Sensitive to heat and cold—Completely deaf—Sensitive to vibrations and to touch—Feeble power of smell—Taste—Mental qualities—Nature of food—Omnivorous—Digestion—Leaves before being swallowed, moistened with a fluid of the nature of the pancreatic secretion—Extra-stomachal digestion—Calciferous glands, structure of—Calcareous concretions formed in the anterior pair of glands—The calcareous matter primarily an excretion, but secondarily serves to neutralise the acids generated during the digestive process . . . 8-54

## CHAPTER II.

HABITS OF WORMS—*continued.*

Manner in which worms seize objects—Their power of suction—The instinct of plugging up the mouths of their burrows—Stones piled over the burrows—The advantages thus gained—Intelligence shown by worms in their manner of plugging up their burrows—Various kinds of leaves and other objects thus used—Triangles of paper—Summary of reasons for believing that worms exhibit some intelligence—Means by which they excavate their burrows, by pushing away the earth and swallowing it—Earth also swallowed for the nutritious matter which it contains—Depth to which worms burrow, and the construction of their burrows—Burrows lined with castings, and in the upper part with leaves—The lowest part paved with little stones or seeds—Manner in which the castings are ejected—The collapse of old burrows—Distribution of worms—Tower-like castings in Bengal—Gigantic castings on the Nilgiri Mountains—Castings ejected in all countries . . . . . Page 55-128

## CHAPTER III.

THE AMOUNT OF FINE EARTH BROUGHT UP BY WORMS  
TO THE SURFACE.

Rate at which various objects strewed on the surface of grass-fields are covered up by the castings of worms—The burial of a paved path—The slow subsidence of great stones left on the surface—The number of worms which live within a given space—The



weight of earth ejected from a burrow, and from all the burrows within a given space—The thickness of the layer of mould which the castings on a given space would form within a given time if uniformly spread out—The slow rate at which mould can increase to a great thickness—Conclusion

Page 129–175

## CHAPTER IV.

### THE PART WHICH WORMS HAVE PLAYED IN THE BURIAL OF ANCIENT BUILDINGS.

The accumulation of rubbish on the sites of great cities independent of the action of worms—The burial of a Roman villa at Abinger—The floors and walls penetrated by worms—Subsidence of a modern pavement—The buried pavement at Beaulieu Abbey—Roman villas at Chedworth and Brading—The remains of the Roman town at Silchester—The nature of the débris by which the remains are covered—The penetration of the tessellated floors and walls by worms—Subsidence of the floors—Thickness of the mould—The old Roman city of Wroxeter—Thickness of the mould—Depth of the foundations of some of the buildings—Conclusion

176–229

## CHAPTER V.

### THE ACTION OF WORMS IN THE DENUDATION OF THE LAND.

Evidence of the amount of denudation which the land has undergone—Sub-aerial denudation—The deposition of dust—Vegetable mould, its dark colour and

fine texture largely due to the action of worms—  
 The disintegration of rocks by the humus-acids—  
 Similar acids apparently generated within the  
 bodies of worms—The action of these acids facilitated  
 by the continued movement of the particles of earth  
 —A thick bed of mould checks the disintegration  
 of the underlying soil and rocks—Particles of stone  
 worn or triturated in the gizzards of worms—  
 Swallowed stones serve as millstones—The levigated  
 state of the castings—Fragments of brick in the  
 castings over ancient buildings well rounded. The  
 triturating power of worms not quite insignificant  
 under a geological point of view . Page 230-258

## CHAPTER VI.

### THE DENUDATION OF THE LAND—*continued.*

Denudation aided by recently ejected castings flowing  
 down inclined grass-covered surfaces—The amount  
 of earth which annually flows downwards—The  
 effect of tropical rain on worm-castings—The finest  
 particles of earth washed completely away from  
 castings—The disintegration of dried castings into  
 pellets, and their rolling down inclined surfaces—  
 The formation of little ledges on hill-sides, in part  
 due to the accumulation of disintegrated castings—  
 Castings blown to leeward over level land—An  
 attempt to estimate the amount thus blown—The  
 degradation of ancient encampments and tumuli—  
 The preservation of the crowns and furrows on land  
 anciently ploughed—The formation and amount of  
 mould over the Chalk formation . . . 259-304

## CHAPTER VII.

## CONCLUSION.

Summary of the part which worms have played in the history of the world—Their aid in the disintegration of rocks—In the denudation of the land—In the preservation of ancient remains—In the preparation of the soil for the growth of plants—Mental powers of worms—Conclusion Page 305–313

---

INDEX . . . . . 315–326

... und die nächsten 10 Seiten ...  
... and the next 10 pages ...

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  $14\frac{1}{2}$  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 pooriness 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