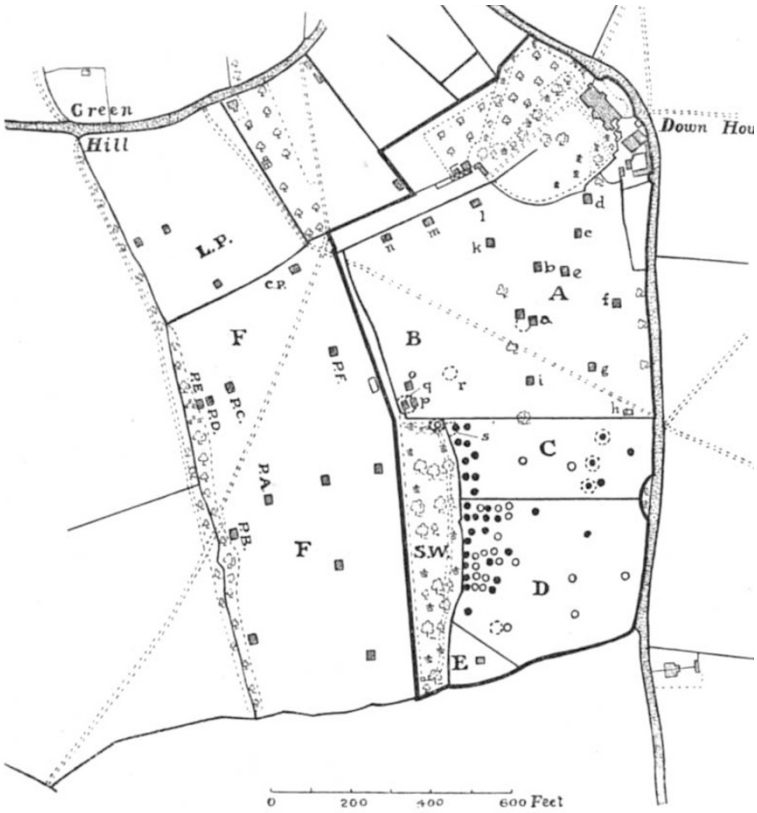
A POSTSCRIPT TO DARWIN'S "FORMATION OF VEGETABLE MOULD THROUGH THE ACTION OF WORMS"

By SIR ARTHUR KEITH, F.R.S.

ON December 20, 1842, three months after taking up residence at Downe, Darwin spread "a quantity of broken chalk over a part of a field near my house" with a view "of observing at some future period to what depth it would become buried". Twenty-nine years later—1871—he had a trench dug across this part of the field; "a line of white nodules could be traced on both sides of the trench at a depth of 7 inches from the surface. . . . Another part of this same field was mossy and it was thought that sifted coal cinders would improve the pasture, a thick layer was spread over this part either in 1842 or 1843, and another layer some years afterwards". In 1871 a trench was dug revealing a line of cinders at a depth of 7 inches and another parallel line at 5½ inches". (These citations are taken from pp. 139, 141 of the 1881 edition of Darwin's book, "The Formation of Vegetable Mould through the Action of Worms"; in the remainder of this article, I shall cite merely the page number. Darwin began observations on the formation of mould in 1837 while staying at Maer, Staffs, the home of Josiah Wedgwood—his uncle (and future father-in-law). His observations of that period were communicated to the Geological Society of London on November 1, 1837.)

Anyone who is interested in Darwin's experiment and who wishes to ascertain what has become of his line of chalk nodules and of sifted coal cinders after the lapse of a century is met at the threshold of his inquiries by the fact that Darwin gives no indication of the part of the field on which chalk and cinders were spread, nor are we certain of how much he included under the term 'field'. At present the twelve acres (Ordnance Survey gives 14·4 as the acreage of Darwin's field) of pasture land which was purchased with Down House* is divided into three meadows (see accompanying figure)—a north meadow (*AB*) near Down House, a small middle meadow (*C*) and a distant or south meadow (*D*) now used as a cricket field. The sandwalk (*SW*) which bounds these meadows on the west was acquired from Sir John Lubbock at a later date. The pasture land was so divided during Darwin's lifetime, but when he speaks of a "field", apparently he does not refer to a meadow but to the whole of the twelve acres. Major Leonard Darwin agrees in this interpretation and cites the following passage from "Life and Letters of Charles Darwin" written by his brother Francis: "Eighteen acres of land were sold with the house, of which 12 acres on the south side of the house form a pleasant field" (vol. 1, p. 321). In writing to his sister Susan in 1845, Darwin mentions a mound which hid "part of the field". Yet on p. 298 of his work on the formation of mould we have this passage: "It may be well to recall here the case of fragments of chalk buried beneath worm-castings on one of my fields."



A PLAN OF DARWIN'S MEADOWS WITH SITES AT WHICH SOUNDINGS WERE MADE.
A B. North meadow; the sites of trenches are numbered *a–r*.
C. Middle meadow; *D.* South meadow or cricket field. The sites at which chalk was found are marked by black circles, those in which chalk was absent by open circles.
E. "Little Canada".
SW. Sandwalk.
FF. Great Pucklands. *LP.* Little Pucklands.
CP. Chicory patch.
Other explanations in text.

Even if we agree that Darwin included all twelve acres under the term "my field", we have still to discover the parts on which he spread chalk in one case and sifted cinders in another. Major Leonard Darwin, on my appealing to him, thought the most likely area to receive an application of cinders would be that part of the north field (*A*) lying adjacent to the house—the north-east corner—and it is in this area that my trenches reveal the cinder-layer at its thickest; but cinders, fragments of unburned coal, of brick and of tile were found throughout the twelve acres—all at the same uniform depths. Chalk was found nowhere in fields *A*, *B*, with the exception of one small pocket to be mentioned later. It was found in that part of the cricket field lying

* "Downe" is the spelling given by the Ordnance Survey for parish and village; "Down" is the spelling used by the Darwins for their home.

by the side of the sandwalk and in the adjacent field *C* —an area less than an acre in extent. Major Darwin had no direct knowledge of the site when I informed him of my discovery of chalk nodules in the cricket field; he wrote: "Memory plays me many tricks, but I now have an idea or memory that chalk was put on the field near the sandwalk because it was felt it would look ugly near the house."

Before proceeding to describe what was revealed by my trial trenches in Darwin's field let me turn for a moment to an eleven-acre field which bounds the Darwinian property on the west (*FF*). It was in the first stage of becoming pasture land when Darwin arrived in 1842, having been last ploughed in 1841, and has remained in pasture ever since. The larger part of this field is on the flat upland, but its western part slopes rapidly down over the brow of an adjacent valley or coombe. "The field," writes Darwin, "was always called by my sons *the stony field*. When they ran down the slope the stones clattered together. I remember doubting whether I should live to see these larger flints covered with vegetable mould and turf. But the smaller stones disappeared before many years elapsed, as did every one of the larger ones after a time; so that after thirty years (1871) a horse could gallop over the compact turf from one end of the field to the other and not strike a single stone with his shoes."

The local name for the stony field is Great Pucklands. In 1931, three years after he had purchased Darwin's home and grounds, repaired and endowed them and transferred them as a trust to the British Association, Sir Buckston Browne bought Great Pucklands and the adjacent Little Pucklands and gave them to the Royal College of Surgeons of England as a site for a station or farm for surgical research, which was also endowed by his munificence. Thus it was I came to make my home in Downe and to make an acquaintance with Darwin's "stony field" and ultimately to wage war upon its weeds.

At the beginning of 1941, Dr. Colbeck and I, being in need of winter fodder for the College guinea pigs, ploughed half an acre of Great Pucklands to a depth of six inches and sowed out in chicory and kale. In the spring of the present year (1942) the kale having been uprooted and the chicory blades having died down, this half-acre presented the stony appearance that had met Darwin's eye over the whole of Great Pucklands a century before. I marked out half-a-square yard (36 in. by 18 in.) between two of the chicory rows; loose flints on the surface numbered 137, weighing collectively 14 lb.; I sifted the soil underneath down to a depth of 8 in. and obtained more than four hundred flints (varying in weight from 15 gm. to 450 gm.) and weighing collectively 39 lb. Thus in every square yard down to a depth of 8 in. there were 106 lb. of flints, amounting in round numbers to 230 tons per acre. The re-assortment of soil and flints, effected by worms in Great Pucklands during the past century was revealed by sections made in various parts of the field both on the level and on the slope.

Let me first compare the section which Darwin made in 1871 with one I have just dug at or near Darwin's site (*PA*). His section revealed (p. 144) an upper stratum, rather less than three inches in thickness, of stone-free mould (including turf) and a lower stratum which he described as "a coarse clayey earth full of flints". While the evidence from his own fields indicated that worms threw up mould at the rate of an inch in five years, here the evidence was of a much slower rate, namely, an inch in twelve years. My section showed the same thickness of stone-free mould as did Darwin's. In my section it varied from 2·5 to 3 in.; under the mould came a "stony stratum" 5 in. in thickness and containing more than one thousand flints, similar in size to those met with in the chicory patch, the stones being held together by Darwin's "coarse clayey earth". In all sections of our turf-land over the chalk this "stony stratum" serves as a bench-mark, particularly its uppermost stones, which form a kind of pavement. Under the stony stratum, beginning at a depth of 8 in., came weathered clay with numerous flints, which I dug to a depth of 15 in. from the surface without finding any object foreign to the clay.

Thus it will be seen that in the seventy-one years which have come and gone since Darwin made his record the surface strata on the declivity of Great Pucklands have remained in a state of equilibrium. Some of the factors which help to maintain a stationary position in spite of worm action, or rather because of it, are suggested by other sections I made along the valley-set part of Pucklands. Some thirty yards farther down the slope than the trench just described (*P B*), the field ends on the side of the valley in a steep bank, occupied by a belt of ancient beech trees. As the bank is approached the land becomes nearly level. Rank grass grows here which every autumn becomes cluttered with brown beech leaves—food for the worms. Here I expected to find the soil deep, and that I think would have been Darwin's expectation. To my surprise my spade struck the stony stratum before it was three inches into the turf. The mould was intensely black in colour, very friable, and was 2½–3 in. in thickness. The underlying stony stratum was 6 in. in thickness and, again to my surprise, the clay under the stony stratum was white with chalk nodules, the chalk being 3 in. under the stony stratum and continuing to a depth of 14 in.—beyond which I did not dig. The earth between the flints of the stony stratum was very black and had in it much decayed fibrous material; there was ample evidence of worm action in the stony stratum and in the overlying mould but none in the chalk. Darwin must have known that a stratum of chalk serves as an efficient worm barrier. Under the walk of his kitchen garden there are 8 in. of chalk, which although laid down in 1845, still keeps worms from reaching the gravelled surface. When he laid down the "sandwalk" he used chalk as a foundation. So with the trench just described; the underlying chalk seems to limit the traffic of worms in a deepward direction. I ought not to have been surprised at finding chalk in the depth of this trench, for along the side of the coombe, at the level of the beech bank, is a series of disused chalk pits.

Other trenches dug into the more level ground, above the beech bank and about a hundred yards to the west of the one just described (*PC*, *PD*, *PE*), throw light upon the manner in which the stony stratum, in a long-established pasture, is maintained at a fairly constant level. The trench I am now to describe lies in the middle of the zone which becomes so thickly covered with beech leaves every autumn and from which they vanish in early summer. There were ample signs of worm casts at the site; I counted eight fresh ones in an area of two square feet and as I cut the turf counted eight worms. The surface mould was black as soot but only 2½–3 in. in depth. The stony stratum, 4 in. in thickness, contained black sandy earth with black vegetable fibre; below

the stony stratum came a fine sandy loam with a line of chalk nodules in it, three inches below the stony stratum. While the mould was black the underlying loam was snuff-coloured, so that any mixing of the black mould with the underlying loam was easily detected. It was clear that the worms were conducting a double-way traffic; the black-coloured mould carried into the deeper loam seemed to me to exceed the amount of loam added to the black soil. If the loam brought above the stony stratum by worms is equal to the mould which they and the rain carry through the stony stratum, then a condition of equilibrium would be attained.

So far I have been dealing with sections made on the sloping parts of Great Pucklands; but before returning to Darwin's own field it will be helpful to examine a typical section made through the turf on the flat area of Pucklands. Here, as in Darwin's field, the surface soil is separated from the underlying chalk by a red clay varying from 8 to 14 ft. in thickness and containing numerous flints. The section I shall describe is one made about 120 yards to the east and south of the chicory patch (*P F*). In my earlier trenches I first removed the turf with 2 in. of soil from an area measuring 36 in. by 18 in. (half a square yard) and then deepened this area, 2 in. at a time, until a depth of 14 in. was reached. The material from each 2-in. level was sifted, the contents of my sieve being noted for each level—flints, pebbles, brick, tile, cinder, charcoal, iron, etc. I took my levels from a straight edge laid across the trench resting for 6 in. on the more level and shorter turf on each side of the trench.

After a time, finding the soil structure to be uniform throughout the level pasturage of this neighbourhood, I replaced this tedious method by a simpler one which I shall now illustrate in connexion with the trench I am to describe—that to the south-east of the chicory patch (*CP*). My spade, a light one with straight blade, 6 in. wide and 9½ in. in depth, sinks easily through the short turf and grates against the stony stratum at a depth of 4 in. or 4½ in. A little movement of the handle causes the turf, and soil under it, to separate from the stony stratum, where the roots of the herbage end, only the deeper rooted weeds—the dock, thistle, knapweek, etc., penetrating the stony stratum to the subsoil of weathered clay (often sandy) underneath. In the chicory patch the flints were intermingled with the soil; but here the worms have thrown the soil up and permitted flints and all foreign bodies which may happen to have been present in the soil at the time of ploughing, cinders, bits of tile and brick, etc., to subside into the stony stratum. Anything thrown on the turf later will be arrested in its submergence when it reaches the stony stratum. Any foreign body found under the stony stratum was probably *in situ* before the stony stratum came into being. The turf, with the underlying mould, as I have said, separates easily and naturally from the stony stratum. When we turn its deeper surface up to the light, we find the openings of worm burrows, a few of the worms and some of the looser small flints which have come away from the stony stratum with the turf. In this particular trench (*P F*), I was surprised by a complete absence from the deep aspect of the turf of small pebbles, cinders, fragments of brick, etc., which are so abundant at this level in the neighbouring Darwinian fields. The removal of the layer of turf exposes the upper aspect or pavement of the stony stratum—the chief level of worm activity and of mole activity. Worm chambers were noted here but only two polished pebbles; usually there are a dozen of such pebbles, smooth and glistening, apparently from the friction of worm movement. The stony stratum was made up of flints of the same size and number as were loosely strewn through the soil of the chicory patch. I dug to a depth of 14 in. from the surface—that is 5½ in., into the weathered clay under the stony stratum—but found only virgin ground. There was no trace of chalk to be seen.

With the experience of Great Pucklands to fortify us, we are now to make a survey of Darwin's meadows beginning with a triangular enclosure about half an acre in extent known in recent days as "Little Canada" (*E*); it is at the southernmost extremity of Darwin's land, beyond the cricket field. It had been a vegetable garden but twenty years ago it was left at the disposal of Dame Nature, who made it into a wilderness of thorn, blackberry, wild-rose, traveller's joy, with an abundance of thistle and nettle. In January of the present year (1942) with Dr. Howarth's consent, I began its clearance, but after the clearance and before ploughing, made an examination of the soil structure, similar to that made in the chicory patch. In twenty years, worms had covered the larger more superficial flints with a layer of black mould less than half an inch in thickness (1 cm.); between these superficial stones the mould was about 3 cm. thick—perhaps 1½ in. Darwin knew that worm castings accumulate very slowly on the surface of ploughed land but gave no explanation. There is no lack of worms in "Little Canada"; in the loosely knit upper soil they seem to be able to get rid of their castings without actually emerging on the surface—as they have to do when the soil is covered by dense turf.

I dug a trench of the usual size (36 in. by 18 in.) down to a depth of 15 in., sifting each level as I deepened my trench. I found, but not clearly defined, three strata; the uppermost ended at a depth of 2 in., which I shall label *A*; below *A*, came *B*, three inches in thickness (3rd, 4th and 5th inches); and deepest of all *C*, extending from the 5th to the 15th inch. There were two levels or zones at which foreign material had accumulated—namely, in *B* (which represents an initial stage in the formation of a stony stratum); in this there were many fragments of unburned coal, cinders, pieces of brick, fragments of pottery; the second foreign zone was in *C*, namely, between the 8th and 10th inch. At this level in *C* occurred fragments of coal and of charred wood, pieces of brick and seven nodules of chalk (at the 10th inch level). The flints in the upper stratum (*A*) numbered 138, in *B* 353, in *C* 550.

We now enter the "cricket field" in search of the site of Darwin's experiment with chalk chips and bend our steps to that part which adjoins the sandwalk. Here the zone of the field which adjoins the sandwalk, about twenty yards in width, is now, and has been for many years, undermined by moles. On and near their 'heaps', in one particular part, lying near where a gate enters from the sandwalk—towards the north-west corner of the field—there are many fragments of chalk. Chalk does not occur in earth thrown up by moles in any other of Darwin's meadows. My trenches in the bigger field (*A*,*B*) uncovered not a single nodule of chalk; only in a zone adjoining the sandwalk did my trenches reveal chalk with any degree of constancy; and even here there was no certainty; a trench might reveal an abundance and the next trench dug within the chalk area

and within a few yards of the first yield not a trace.

The area on which Darwin spread chalk was apparently a zone of the cricket field adjoining the area which later became the sandwalk, about 25 yards in width and extending from one side of the cricket field to the other—about a hundred yards in extent. The chalk zone continues into the adjoining or mid-field, ceasing when the northern boundary of that field is reached. In the sketch map the soundings which yielded chalk are indicated by black circles, those which were free from chalk are indicated by open circles. The trenches which reveal chalk are most thickly grouped on the border of the sandwalk; the chalk area is rather less than an acre in extent. In this area chalk occurs at four levels: (1) on the surface thrown up on mole hills; (2) in the mould at a depth of 3–5 in.; this I regard as chalk which had been thrown on the surface by moles at some time within the last twenty years. It occurred at this level in nine of the fifty-five holes I dug in fields *C D*. The third level at which chalk occurs is that at which Darwin found it in 1871, namely, 7 in. I infer Darwin measured to the deepest point of the chalk level, the nodules thus occupying the whole depth of the 7th inch. Now this level lies invariably within the "stony stratum" which usually begins at 4–4½ in. from the surface and extends to a depth of 8–8½ in., at which level the subsoil of weathered clay or sandy loam begins. In only nine of the fifty-five holes dug was chalk found at the Darwinian level. If the chalk I have found at the 7-in. level is a remnant of Darwin's spreading, as I believe it to be, then there has been no movement since 1871. The fourth chalk-level is 3–4 in. under the stony stratum, embedded as big nodules in the soft clayey-loam, occupying a very definite and regular zone. This was by far the most constant level at which I found chalk. In the thirty-four soundings which yielded chalk in fields *C* and *D* the chalk occurred at this deepest level, namely, 9–12 in. beneath the surface in twenty-five instances.

Does this deep chalk represent a remnant of that spread by Darwin in 1842? I am convinced, for various reasons, that it does not, but had been at the level we now find it long before Darwin's time. Darwin was confident that his field had been in pasture for at least thirty years before he came to Downe—probably, he adds, for "three times thirty years". We may be certain that a stationary stony stratum was already in existence long before 1842. Could the chalk nodules penetrate this stratum and so reach the subsoil? Let me quote Darwin's actual words touching this point (p. 140): "Beneath the line of chalk nodules there was in parts hardly any fine earth free of flints, while in other parts there was a layer, 2½ in. in thickness. In this latter case the mould was altogether 9¼ in. thick; *and in one such spot a nodule of chalk and a smooth flint pebble, both of which must have been left at some former time on the surface, were found at this depth*". I have italicized part of the last sentence, for Darwin, too, was apparently suspicious of the deep chalk as being of his sowing. I have seen 'break throughs' in the stony stratum; they are rare; the stratum is usually intact and the chalk nodules in the subsoil are regular—not haphazard in their disposition. Chalk also occurs outside the 'chalk zone'—in the eastern part of field *C* and in the adjoining part of the cricket field. Here it occurs at the deepest level.

What I have observed in nowise invalidates Darwin's experiment. He spread chalk on the turf and in twenty-nine years found that it had become buried by worm action to a depth of 7 in. Under the dissolving action of rain, of root action and of organic acids in the soil, angular pieces had become reduced to rounded nodules. In the seventy-one years that have come and gone since he examined his line of chalk nodules exposed in section, the solvent action of rain, of root and of soil continued on the chalk nodules and only traces of his experiment are now to be found. But the deep chalk which was *in situ* before the field was last ploughed, perhaps a century before Darwin's day, is protected from these agencies by its depth and still survives as nodules of considerable size (30 mm. by 30 mm. by 20 mm.).

The part of the field which was 'mossy' and over which a thick layer of "sifted coal cinders" was spread, I believe to have been, as Major Darwin suggested, that area of the north meadow (*A*) which lies adjacent to Darwin's house and lawn. Every one of the twenty soundings I made in the north meadow (*A B*) revealed a line of cinders in or near the 6th inch, counting from the surface, but the cinder layer in the area lying towards the house was much richer and thicker than elsewhere.

As already explained I dug my earlier trenches, spit by spit, sifting each as my trench deepened. We may take the results from a trench dug in meadow *A*, within fifty yards of Down House, as representative of the richer area. The vegetable mould, sifted down to a depth of 4½ in. left in my sieve nine small flints, four pebbles, two cinders; the next spit, down to a depth of 6½ in., thus including the upper level of the stony stratum, eighty flints, large and small, forty-eight pebbles, ninety-five cinders (including among these many fragments of uncharred hard coal or anthracite), four fragments of brick and several other foreign bodies; the third spit, down to a depth of 8 in., thus including the rest of the stony stratum, gave 328 flints, forty-four pebbles and only four cinders. Deeper than 8 in. no foreign object was found in this trench, but in others pieces of brick and tile were frequently observed. Indeed it may be said that fragments of brick and tile are to be found everywhere in Darwin's meadows, both in the upper and lower levels.

When, in 1871, Darwin dug a trench he observed "many cinders lay in a line at a depth of 7 inches from the surface". Here, as in the case of his line of chalk nodules, I infer his measurement refers to the deepest point reached by the cinders. In the seventy-one years which have elapsed since Darwin made his sounding, although worms have been throwing up castings every year, the cinder layer has certainly not become deepened in its level. Having subsided, under worm action, to the bottom of the vegetable mould, cinders and all foreign objects become arrested on and between the upper flints of the stony stratum and there remain until they are dissolved by soil agencies. Indeed my data indicate that the thickness of the vegetable mould in Darwin's meadows has diminished to an extent of half an inch, perhaps a whole inch. More has been washed out, or taken out of the soil, than has been returned to it. There has been much and prolonged hard farming.

I was able to verify and extend another of Darwin's observations recorded in the following passage (p. 141): "In another part of this field, which had formerly existed as a separate one" (see *B*) "which it is believed had been pasture land for more than a century, trenches were dug to see how thick

the vegetable mould was. By chance the first trench was made at a spot where, at some former period, certainly more than forty years before, a large hole had been filled up with coarse red clay, flints, fragments of chalk and gravel; and here the fine vegetable mould was from 4⅛ to 4⅜ in thickness". In a corner of field *B*, situated at the north end of the sandwalk, there is still to be seen a wide hollow, which, before it was filled up, had perhaps served as a cattle pond (*p.q*). Digging here, where grass grows rank and strong, I found the vegetable mould measured 3½ –4½ in.; under it came a thick stratum of flints and at a depth of 8½ in. below the surface, several large blocks of chalk but I failed to find the coarse red clay. This, however, I found in an adjacent hollow of the neighbouring field (*s* in *C*). In this neighbouring site the mould, which is very black, for the hollow is shaded by trees of the sandwalk, measures only 2–3 in. in thickness and showed much evidence of worm activity. The black mould rested directly on a red plastic clay, which yielded to the spade as if it were cheese. In the red clay could be seen long 'test-tubes' or fingers of black mould which worms had carried from the shallow surface layer into the cheesy red-clay. The worm castings were black; none were red. Thus it will be seen that the vegetable mould covering the sites of two former holes at the northern end of the sandwalk, remain much as they were in Darwin's time. The mould has not increased in the past seventy-one years; such slight evidence as there is points rather to a diminution in thickness.

Perhaps readers may recall the passage (p. 145) in which Darwin gives an account of a "narrow path running across my lawn, paved in 1842 with small flag-stones set on edge; but worms threw up many castings and weeds grew thick between them. . . . The path soon became almost covered up, and after several years no trace of it was left". In 1877 Darwin removed the turf and found the path "covered by an inch of fine mould". One would like to know how deep that path now lies in Darwin's lawn but Dr. Howarth and I have 'sounded' and searched for it in vain. But I suspect it is covered by at least 5 in. of mould, for the fork I used in my soundings had prongs of that length.

Summary. I have given in this article an account of the chief facts revealed by digging trenches, some seventy in number, in the fields at Downe, which supplied Darwin with so much of his data for his work on "The Formation of Vegetable Mould through the Action of Worms". The main result is to prove that after a time chalk, cinders or other foreign bodies, when spread on the turf, do not continue to be buried deeper and deeper by worm action, but reach a stationary level. This is due to the fact that, in the fields at Downe, the action of worms is two-fold; they throw up on the surface a stone-free vegetable mould; they cause flints and all solid objects in the soil to subside into a stony stratum. When objects have reached the stony stratum they remain stationary. When a stone is thrown in a pond it sinks to the bottom and there remains; it is the same if we cast an object upon permanent turf; under the action of worms it sinks to the bottom—the stony stratum and there abides. Plentiful remains were found of the cinders spread by Darwin a century ago; but his chalk chips have almost disappeared. Objects found in the subsoil under the stony stratum are survivals from the period which preceded the last ploughing.

BIOLOGICAL ASSAY OF INSECTICIDAL SPRAYS

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MORE than a hundred and fifty different kinds of insects have been found from time to time on stored produce, but only a dozen or so are found often and in dangerous numbers. The control of these insects is a matter of considerable economic importance, more particularly when foodstuffs susceptible to attack by them are kept in store over prolonged periods and wastage must be avoided. The use of insecticidal sprays as a control measure, in warehouses where grain, dried fruits, cacao, etc., are stored, is comparatively simple and, when properly applied, has been shown by experience to be effective, provided the infestation has not been allowed to reach too great proportions. The Pest Infestation Laboratory of the Department of Scientific and Industrial Research is therefore carrying out a study of these insecticidal sprays as one of the chief items in its programme of research on ways of combating infestation of stored produce by insects. Special attention has been given to the development of a method of comparing the killing power of different sprays since it was evident that a comparative test of this kind was essential as the next step in the process of improving insecticidal sprays. The technique of the test which has been successfully worked out at the Pest Infestation Laboratory is described in the second half of this article.

As a control measure spraying has the advantage of being simple and safe to both operator and goods, if done with reasonable care. The chief requirements of an insecticidal spray are that: (1) it should be toxic to as many of the common pests of produce as possible, in the concentrations which can be economically applied; (2) it should retain that toxicity as long as possible after it has been applied; (3) it should not be toxic to man; (4) it should not taint goods to which it may be applied; and (5) it should not be inflammable. A spray may kill insects by direct contact, by leaving a toxic film on surfaces, or by evaporating to give a poisonous vapour, thus acting as a local fumigant.

The first scientific study of the use of a pyrethrum–oil mixture as a spray for controlling infestation in warehouses was carried out for the Australian Dried Fruits Board by the Department of Zoology and Applied Entomology of the Imperial College of Science and Technology under Prof. J. W. Munro between 1931 and 1938. This is described in two papers by Dr. C. Potter[1]. This work was designed to develop a method of controlling the infestation of dried fruit in warehouses by the moths *Plodia interpunctella* Hb. and *Ephestia elutella* Hb. At first, the technique consisted of filling the warehouse with a finely atomized mist of a mixture of pyrethrum extract in a heavy, highly refined white oil. This process was carried out every evening during the period of emergence of the moths. Although this was found to be effective, it was expensive in labour and materials, involving a lengthy spraying process every day for a period of at least three months. It was found later that the effectiveness of the pyrethrum–oil spray was largely due to the fact that, when it settled, or was sprayed directly on to a surface, it left a film which remained toxic to moths and