To
A.A.
A.E. and E.D.

THE LIVING SOIL

evidence of the importance to human health
of soil vitality, with special reference
to national planning

by

E. B. BALFOUR

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FOREWORD TO THE REVISED EDITION

When, on the occasion of this book's debut in America, I lightheartedly agreed to revise it and bring it up to date, I had no idea how formidable a task I had undertaken.

When the book was first published I sent a copy to a friend, warning him that it contained very little original work. He was kind enough, in his reply, to say that while most of my bricks might have been made by others, the mortar which held them together and the design of the building were both essentially mine.

I have told this story only because I want to use his metaphor to explain my difficulties with the present edition and to excuse the results of my labours.

One repercussion of the 'building's' first appearance was that people from all over the world began sending me more bricks. Some of them were so important or interesting that I felt compelled to add them to my building. So an extra gable here or an added bow window there kept appearing every time a new edition went to print. Sometimes my collection of new bricks even necessitated building outhouses.

My plan, when I undertook to rebuild and modernize, therefore, was to pull down parts of the building and re-design them to incorporate all these afterthoughts--these tacked-on excrescences--into the main structure, together with the newest lot of bricks.

When I began, however, I found I had forgotten the landscape. My building was erected in 1942 surroundings, and do what I would I could not design a 1948 building that would tone with them.

So I was faced with two alternatives; either I had to demolish the whole structure, cart the materials away and rebuild from the foundation in a 1948 setting, or I had to be content to compromise by pulling down the many extensions and, with the addition of some of the newest bricks, rebuilding them into a modem wing while leaving the main structure unaltered. I chose the latter course. The result is a house of mixed periods--like so many that exist in England. Parts now tone with the landscape and parts do not. Every now and then the levels of the floors alter with an odd step up or down--up to 1948 and down again to 1942. If this proves to be a little more confusing to a new-comer, than a house that is all of a piece, I can only hope that it will not be less interesting on that account.

The fact is--to drop the metaphor--that I wrote this book, not only in wartime, but at that period of the war when the invasion of this country seemed--and indeed was--a daily possibility; when large parts of London had been destroyed, and when the drone of enemy aircraft overhead was still our nightly lullaby. While the war is only rarely mentioned in the book, it was the background to my thoughts when I wrote it, and as such coloured *the style of the writing.* I found that to try to bring the whole book up to date, merely by altering dates and correcting tenses simply did not work, it only resulted in making the sentences, and the sentiment behind them, seem unreal.

So in the end all I have been able to do, is to incorporate the various afterthoughts into the main text, and to bring, as far as possible, my facts up to date while leaving their setting unchanged.

After all, even the facts won't stay up to date for long, so rapidly is new knowledge being acquired on this most dynamic and vital of subjects--the Living Soil.

E.B.B.

Haughley,
January 1948.

INTRODUCTION

In this book I have attempted something which my friends tell me cannot be done. I have tried to write for both the specialist and the layman. If I have failed, if what I have written proves to be unintelligible and boring to the layman, and at the same time trite and superficial to the specialist, I shall be unable to plead that I was not warned, but my only alternative was not to write at all--a depressing one for the would-be author suffering from the belief that he has something important to say. At any rate I have refused to accept such defeatism, preferring to attempt the supposedly impossible. For there is a good reason why this book could not be written for a limited section of the reading public.

My subject is food, which concerns everyone; it is health, which concerns everyone; it is the soil, which concerns everyone--even if he does not realize it--and it is the history of certain recent scientific research linking these three vital subjects.

Now since it concerns health, and food, and soil, and science, it also concerns post-war planning, and because it concerns all these things, it concerns the legislator, the politician, the voter, the tax- and rate-payer; the farmer, the gardener, the veterinary surgeon, the doctor; the sanitary inspector, the public health authority, the school teacher, the priest; 'Tinker, Tailor, Soldier, Sailor . . .'--in fact, the Citizen. So there was no third choice; I had to write for everyone or not at all.

I have, however, tried to arrive at a compromise, whereby what I have written will, I hope, be acceptable both to the citizen who is also a specialist, and to the citizen who--perhaps because of our modern tendency to urbanize everything--goes by the name of 'the man in the street'.

I have avoided as much as possible the inclusion of too much technical detail in the main text, but have included, in a special section at the end of the book, additional technical data on most of the subjects dealt with. To these the specialist can refer should he want more precise detail concerning the evidence presented.

As it has been impossible to avoid entirely the use of technical and scientific terms, particularly in Chapters IV and V, I have provided a glossary for the benefit of those to whom these terms may be unfamiliar. It is my earnest hope that by these means I shall have confounded the pessimists, for it is quite impossible to overestimate the importance of the subject. That this is becoming increasingly realized, is shown by the spate of publications that have appeared recently concerning it. I make no apology for adding to their number. There cannot be too many, and no two people approach a subject as complex as this from exactly the same angle.

The reader will find that much of this book consists of quotations. I make no apology for this either. The information required to present the picture as a whole--and the subject really amounts to the ecology of life--is so scattered, that the ordinary citizen could not possibly be expected to hunt it all up for himself, even if he knew where to look. One of my objects in undertaking this book, has been to bring together, within the covers of a single volume, a summary of certain recent scientific research on nutrition and on soil fertility, including results that have been obtained in many different parts of the world by practical application of the principles involved.

The cumulative evidence which these results provide of the interrelationship between soil vitality and the health of plants, animals, and man, is of so important a nature, and of such far-reaching implication, that it is high time the general public were given an opportunity to study it, and to form its own judgement thereon: and here, in order to avoid any misunderstanding, I would like to insert a note on terminology.

First. *Soil fertility.* This term is used throughout this book to denote vitality. It is not used as a synonym for productivity. Increased productivity can, and usually does, result from increased vitality. But for a limited period it can also be induced at the expense of vitality. In the former case the increase represents increased income, in the latter it represents reduced capital.

Second. *Artificial (or Chemical) Fertilizers.* These words as used throughout this book refer to manufactured synthetic inorganic chemicals, or more simply still, fertilizers not derived from living, or once living, matter. 'All artificial things are invented, and all are "made" by man. All natural entities are born, and all are grown by Nature." (G. Scott Williamson, M.D.) Quite definitely the term artificial, used in this sense, does not include such organic products as chalk, guano, pure bone or fish meal, etc. Obviously the addition to the soil of animal residues such as these cannot detract from its vital quality, which is the point at issue. The basis of the whole theme is an ecological one, centring round the mutual relationship of the organism and its environment. Considerable light is thrown on the importance to health of a living environment, by the evidence recently published in *The Peckham Experiment,* by Pearse and Crocker, (Allen and Unwin, 1943. See p. 216.)

I am very much aware of the magnitude of the task I have undertaken in attempting to present so vast a theme, and of the impossibility of covering the subject adequately in the space of a single volume. All I can hope to do is to convince the reader of the importance of the issues involved and to whet his appetite for more information. If I succeed in achieving so much, the writing of this book will have been worth while.

I need hardly say that I could not have attempted to write it unaided. The number of people to whom I am indebted for assistance of one kind or another is so large that it is impossible to list them all individually, but as everyone's help was, without exception, of the most generous and disinterested kind, any, whose names I have failed to acknowledge here, will know that they are nevertheless included in my thanks. Special mention must however be made of the following:

Dr. L. J. Picton, for invaluable help with the pamphlet of which this book is really an enlargement. Dr. M. C. Rayner and Professor Neilson-Jones, not only for the contribution of vital material, but also for critical advice, given whenever asked, without stint, and at considerable expenditure of time and trouble. But for the generous way in which these two experts put their knowledge at my disposal, the evidence which I have been able to present in this book would have been very much less complete. Mrs. Ysabel Daldy, for giving me invaluable information concerning New Zealand. The personnel of The Association for Planning and Regional Reconstruction, for the trouble taken in ferreting out tiresome statistics for me. Then there is the long list of those who have supplied me with material and information, or have allowed me to quote from their writings. These include, in addition to all the above, Captain R. G. M. Wilson; The County Palatine of Chester Local Medical and Panel Committees; the Earl of Portsmouth; Dr. G. T. Wrench; Sir Albert Howard; Messrs. Jacks and Whyte; Dr. K. E. Barlow; Lord Northbourne ; Mr. C. C. J. Bullough; Viscount Bledisloe, and many friends who follow the honourable profession of tilling the soil.

My thanks are also due to the following publishers and editors, without whose co-operation the permission of the authors concerned would have been inoperative. Daniel & Co. Ltd.; Dent & Co. Ltd.; Faber and Faber Ltd.; the Oxford University Press; the Cambridge Press; the editors of *Forestry* (the Journal of the Society of the Foresters of Great Britain); the editor of the *Journal of Agricultural Science;* the editors of *Nature;* the editor of *The Empire Cotton Growing Review;* the editor of *The Compost News Letter.*

I am also indebted to the following for some of my facts: P.E.P. Biological Reviews; Dr. Charles Drechsler ; the Winsford U.D.C. ; Mr. F. H. Billington; Messrs. Baker and Martin; Association for Planning and Regional Reconstruction; and various journals and newspapers.

Lastly I must acknowledge the source of some of the photographs which form the illustrations to this book. Plate II, Figs. 1, 2, and 4, are from original photomicrographs lent by Dr. Rayner. Fig. 3 is from an original drawing by McLennan (*Annals of Botany,* 1926). Plate XI is from a drawing by Dr. C. Drechsler reproduced from *Mycologia* (1937). Plate XII is reproduced by courtesy of the Director Californian Earthworms Farms U.S.A. All the other Plates, with the exception of Plates 1, XIII and XIV, are reproductions of photographs appearing in *Forestry.* My grateful thanks are due to the authors and editors concerned for permission to reproduce these plates.

I have only to add that any author's profits which I may derive from the sale of this book, will be devoted to the furtherance of the experimental work described in Chapter VIII.

E.B.B.

Haughley
February 1943.
December 1946.
January 1948.

'Healthy citizens are the greatest asset any country can have.'

WINSTON CRURCHILL
World Broadcast, 22nd March 1943

CHAPTER I.
PRELIMINARY SURVEY

'Who builds a ship, must first lay down the keel
Of health, whereto the ribs of mirth are wed. . . .'
ROBERT BRIDGES

It is almost impossible to open a newspaper to-day without finding reports of speeches, writings or discussions on the future of the human race. The topic is given a great variety of names, 'The New World Order', 'Reconstruction', 'Post-War Planning', and many more. It is good that we should be thinking of these things. But too often the would-be reformers of society, while planning the visible details of this new world, forget entirely to consider the foundation upon which the edifice must be built. Society, like a house, does not start at ground level, but begins quite literally beneath the surface of our planet, within the soil itself. For out of the soil are we fashioned, and by the products of the soil is our earthly existence maintained. If we destroy our soil--and it is not indestructible--mankind will vanish from the earth as surely as has the dinosaurus.

'Man cannot live by bread alone', but neither can he survive in his present form without it. The symptoms of spiritual revival in our age are among the most hopeful signs for the future, but the earthly habitat of man's spirit is his body, and the roots of his physical and mental well-being spring from the soil itself, whether the individual be town or country dweller.

We are fond of extolling the achievements of man and are apt to talk with pride of his 'conquest of nature'. This is at present of the same order as the Nazi conquest of Europe. As Europe is in revolt against the tyrant, so is nature in revolt against the exploitation of man. When man preys upon man it is a form of cannibalism. When man sets out to 'conquer' nature by exploitation, it is no less a form of cannibalism, for man is a part of nature. If he is to survive, he must learn to co-operate with the forces which govern nature as well as with his fellow man. If he refuses to learn this lesson, nature will hit back and exterminate him no less surely than the oppressed masses of tortured Europe are already hitting back, and will shortly exterminate the tyranny that has been ruling them since 1940.

'If mankind cannot devise and enforce ways of dealing with the earth, which will preserve the source of life, we must look forward to a time--remote it may be, yet clearly discernible--when our kind, having wasted its great inheritance, will fade from the earth because of the ruin it has accomplished.'

Those words were written by Professor N. S. Shaler of Harvard University in 1896, in the *National Geographic Magazine* of that year. To-day that time of which he spoke can no longer be termed remote. Does this sound like a wild and exaggerated statement? Those who have made a study of soil erosion throughout the world know only too well the truth of it. Read this summary of what is happening in our world to-day.

'Erosion is always going on, even on some soils which are in a good state of fertility. It begins to matter when the rate of erosion exceeds the rate at which life can invade the mineral rock underlying the soil and convert it into soil. That rate is variable, but always very slow; of the order of one inch in 500 to 1,000 years. It matters desperately when the rate of erosion mounts up to very much higher rates than that, as it often does. A high erosion rate in a few limited areas would be regrettable; but when it covers whole continents, as it does to-day, the fate of the world, and of man with it, must be hanging in the balance. It is very difficult to form a scientifically reliable estimate of the real extent of erosion; but there is enough evidence to show that its incidence is world-wide and severe. No country is wholly exempt, but the big continental areas are generally the most seriously affected. There is a fairly large and growing amount of literature on the subject. Probably the most comprehensive survey is *The Rape of the Earth* by Jacks and Whyte.

'The country which has received most attention in this connection is the U.S.A., and deservedly so, for America as usual is out for records. Alarming statistics can be quoted endlessly. On 56.4 per cent of the land surface of the U.S.A., a quarter or more of the soil has been lost. The total loss of fertility has been estimated at 30 to 50 per cent of the total originally available. The amount of soil annually reaching the sea is between 500 and 1,000 million tons, representing 2,000 million dollars' worth of plant food, or twenty-one times the amount annually removed in crops; but that represents only a fraction of the total damage. Fifteen million acres have been totally destroyed, but this is "an insignificant part of the story, for it is the less violent forms of wastage--sheet erosion--which is doing the bulk of the damage to the land". The Missouri basin has lost an average of seven inches of top soil in twenty-four years. (Professor Chamberlin has estimated the mean rate of soil formation as only one inch in 10,000 years.) In California and elsewhere the new deserts are called "dustbowls". The biggest one has advanced in places as much as forty miles in one year, destroying 2,500 farms. Efforts to stop it by tree planting, etc., have failed. The grazing lands of the West are not exempt, for over-grazing and fires have removed the natural cover. Obviously every other problem with which America is faced sinks into insignificance in comparison with this one. It is already too late to do more than save something from the wreck.

'Much the same is true of many other countries. Australia is probably going faster than America, but has only been under "civilized" influence for one-third of the period. Overstocking and unsound cultural methods are the chief troubles there; there is much gully erosion. The wheat lands of New South Wales are said to be getting visibly worse each year.

'In Africa, the Sahara desert is moving southward at a mean rate of over half a mile a year, the Turkana desert eastward at six or seven miles a year. But the whole continent is suffering from erosion in every known form, the extension of deserts and the creation of new ones. It is well known that Kenya is rapidly becoming infertile and is beginning to suffer from locusts. This is no new phenomenon in Africa, for it is known that the northern Sahara was once the granary of Rome, and it is believed that in Roman times the Congo forest reached nearly to Khartoum, from which it is now separated by 1,500 miles of desert or semi-desert. Erosion is not new, perhaps, but the whole process has been enormously accelerated in the last few years.

'China presents remarkable contrasts between the best and the worst. Some of the best cultivation in the world is practised over extensive areas (the reader is referred to Professor King's classic, *Farmers of Forty Centuries*), yet over areas far more extensive the worst types of erosion prevail. The well-cultivated areas are by no means immune from its effects. Chinese industry and care for the land is unequalled, yet it cannot prevent the periodical destruction caused by the Yellow River floods. This river alone carries down 2,500 million tons of eroded soil a year, equal to one foot on 2,000 square miles. Its bed gets silted up between embankments, which must be consistently raised till its bed is well above the surrounding land. Nothing can save that land or its people when an embankment bursts. All that is largely because fuel is scarce in China and the hills have been denuded to provide it. In this way what was once the hunting-ground of Jenghis Khan has been turned into the Gobi desert.

'In Russia erosion on a serious scale has been going on for a long time, though no reliable estimate of its extent seems to be available. The important feature there is that it has been very greatly accelerated by the much-vaunted large-scale mechanical cultivation which has been introduced in recent years. Russia, with her vast areas of low rainfall and high winds, may be well on the way to rivalling America as a record-holder in rapidity and extent of desert formation.

'In Canada, South America, and India the same tendencies are observable in varying incidence, with, so far as can be seen, no compensating tendency towards increase of fertility. Increase of production must not be confused with increase of fertility. Increased production for human use can be and usually is secured by cashing in on existing fertility and using it up, with the disastrous effects described.

'Most of the land area of the world has now been mentioned, with the exception of Europe. In Europe actual erosion has not occurred on a spectacular scale. Nevertheless it is known, for instance, that in Greece the hill-tops were once forests and the slopes were covered with soil and grass. They are not so to-day. It is also known that there has been a progressive desiccation of the soil in the whole Mediterranean region during at least the past 300 years. Terraced cultivation used to be more prevalent and more carefully maintained than is the case to-day, and forests have been destroyed for fuel. There is reason to suppose that the washing-down of hillsides is proceeding in places at a dangerous rate; for instance, in Savoy at least 100,000 acres of good land have been spoilt by coarse silt deposited on them during floods. In England the blowing away of certain of the light fen soils has attracted attention recently.

'But serious erosion is only the culminating stage of a process of which the initial stage is usually loss of fertility of one kind or another. Loss of fertility is vastly more extensive in its incidence than erosion. A picture of the extent of erosion gives merely an indication of the much greater incidence of loss of fertility. If erosion represents the death of the soil, and is as extensive as it appears to be, how much land is partway towards death? The question would be pertinent if the rate of erosion were steady. But it is not steady, it is increasing very rapidly almost all over the world. *Probably more soil has been lost since 1914 than in the whole previous history of the world.* (Italics mine [author]) This is not a natural phenomenon in the ordinary sense of the word. There cannot be any doubt that so far as the modern growth of deserts is concerned it is not nature but man who is the desert maker. It is not unlikely that most of the great deserts of the world are of his making. When we consider how he sets about it now in conjunction with the fact that traces of high civilization are found in many areas now desert, the probability of his past guilt becomes greater. And the exhaustion of the fertility of the soil is no new thing, nor is the temptation to practise it for immediate gain. The new feature in the situation is that man has recently enormously extended his physical powers by the use of mechanical devices. One man can now do what used to be the work of dozens or even hundreds, and can do it faster.

'Natural erosion is either very slow, or, where it is relatively rapid, it occurs only under special conditions, such as are found on high and barren mountains. Nor does a high rate of erosion necessarily accompany cultivation. Some areas, for instance parts of China, have been highly cultivated for at least 4,000 years without loss of fertility, and probably with an accretion of fertile soil rather than with a loss of soil.

'Man sets about his desert-making in various ways. He alters the texture of the soil by using up humus and failing to replace it-by failing to feed the soil with organic matter; livestock are the great converters of otherwise unwanted organic matter to a form in which it can be used by plants. Stockless farming, understocking, burning straw, etc., are all cases of failure to observe the "Rule of Return" which is the essence of farming. Only by faithfully returning to the soil in due course everything that has come from it can fertility be made permanent and the earth be made to yield a genuine increase.' (Lord Northbourne, *Look to the Land* (Dent & Co., 1930).

Some of the repercussions of the rapidly extending area of man-made deserts will be considered in a later chapter. At the moment the sentence in this quotation to which I want specially to draw your attention is 'If erosion represents the death of the soil ... how much land is partway towards death?' This phrase,'the death of the soil' is no figure of speech. Soil is a substance teeming with life. If this life is killed, the soil quite literally dies. It is the living organisms in soil, and the products resulting from their activities, that differentiate soil from subsoil.

Subsoil is derived from the crumbling surface of the rock which forms the earth's crust. It is therefore classified as mineral, and measured in terms of inorganic chemistry. The mistake has been to extend this conception to top soil, for by the time subsoil becomes soil it is no longer wholly inorganic. Soil is a mixture of the disintegrating mineral rock, and humus, with its population of micro-organisms. The number of micro-organisms in soil has been estimated to reach tens of millions to the *saltspoon full!* F. H. Billington, *Compost* (Faber and Faber, 1942). The two are inseparably intermingled, and growth and reproduction cannot long be maintained under natural conditions in the absence of humus, for besides the growth-promoting substances which it contains, it is the humus which gives to soil its texture, its stability, and much of its capacity for retaining moisture.

Humus is 'a product of the decomposition of animal and vegetable residues brought about through the agency of micro-organisms' (Waksman) but it is far from dead in the sense of having returned to the inorganic world from which all life originally sprang. It is still organic matter, in the transition stage between one form of life and another. Once the inorganic passes into the organic, and this is a constant process, it is subject to continual change within the organic cycle, the variety in the forms of life through which it may pass being almost endless.

In our modern world, which is largely ruled by chemistry, we have tended to overlook this continuity of the living principle in nature. Chemists have discovered that we, and all other living things, consist of a few chemicals and a lot of water, but their methods are incapable of revealing the essential nature of the most important ingredient of all, because that ingredient does not survive the tests necessary to determine the others. I refer of course to the ingredient of life itself, which permeates each individual cell of all the countless millions that go to make up the plant or animal body.

Our over-reliance on the chemist, and our readiness to accept his negative outlook on life, have led to a host of troubles, not least of which has been our attitude to the soil, and our habit of thinking of birth and death--in so far, at any rate, as the physical world is concerned--as a beginning and an end, instead of as merely two phases of a continuous process, of which other phases are growth, reproduction and decay, all equally important.

This ever recurring cycle of birth, growth, reproduction, death, decay, decay passing once more into birth, is often called the Wheel of Life. Such similes irritate some people and are helpful to others; I have rather a weakness for them myself, though they can often be misleading. In this case, however, I would choose to liken life to a continuous cable rather than to a wheel, the organic cycle represented by one of its strands, and each phase of it, birth, death, etc., as one of the threads in that strand. For there are other strands in life. The inorganic cycle is one; spiritual values are another. These various strands run parallel to each other, but are nevertheless interwoven at every point just as are the separate strands of a cable, so that if any thread of any of these strands is broken the whole cable is thereby weakened. This book is mainly concerned with the strand representing the organic cycle, for it is man's ignorant interference with this cycle which has produced the effects now threatening his very existence. By ignoring the law of return man has weakened the thread called decay. It is perilously near breaking. If we let it break beyond repair we face starvation.

'Out of the earth are we and the plants and animals that feed us created and made, and to the earth we must return the things whereof we are made if it is to yield again foods of a quality suited to our needs.' (McCarrison. See page 27.)

Evidence is steadily mounting to suggest that our failure to conform to this law of return is already producing, even in this country, the first signs of a dying soil, and the first symptoms of starvation in our population, namely an increase in the many ailments that spring from malnutrition. These are evident in our crops and livestock, as well as in ourselves.

It is the first purpose of this book to present some of this evidence and to show that, when considering matters of health, it is misleading to separate man, animals, and plants. All are part and parcel of the same nutrition cycle which governs all living cells. If we attempt interference with it, other than along the general lines of co-operation, dire results follow. This fact is admirably explained and described in a recent book by Dr. K. E. Barlow, *The Discipline of Peace,* Faber and Faber, 1942. But even his comprehensive survey has omitted a vital link in the cycle. He shares the common misconception that soil can be considered as an inorganic raw material. 'The dependence of the animal on the plant,' he writes, 'is in respect of energy and discipline, exactly parallel to the dependence of the factory upon the steel works. Animal food is a modified product, just as metal is . . . life first of all encounters the inorganic and elaborates certain materials from it by a process which is called metabolism. As we pass from the plant to the animal cell, life no longer encounters what is inorganic; the raw material on which it now works is metabolised material. What has happened has been that a second cycle of metabolism has been integrated with the first, and with each new cycle, the scope and perfection of the discipline practised within the living organization is increased.'

This first cycle, by which the inorganic enters the organic, is certainly one of the strands in my metaphorical cable, but it is not the only one with which plant life is concerned. Interwoven with it is one of the threads of the organic cycle. The vegetable kingdom has for too long been considered as a sort of factory concerned only with converting inorganic salts into metabolised material for the benefit of the animal kingdom, without payment. It is now becoming realized however that to fulfil this function it demands its price. If the inorganic world supplies much of the raw material, the world of micro-organisms must supply much of the motive power; these micro-organisms in their turn depending upon the animal and vegetable kingdoms for their sustenance.

In other words, by the time food reaches the animal, much of it is entering, not its second, but its third and even fourth cycle of metabolism, for recent research has provided evidence, as I shall later show, that part at least of the food utilized by plants is a highly complex material already metabolised by bacteria and soil fungi from the organic substances of the higher plants and animals, thus completing the full cycle of life, death, decay, and rebirth.

Quite a strong case can be made out for believing that it is, at least in part, because we have ignored the dependence of plant life upon the action of soil fungi, that sickness to-day costs Great Britain, directly or indirectly, the formidable sum of 300 million pounds sterling every year. ('Nothing like a balance sheet can be drawn up of the total annual economic loss suffered by the nation through accidents and sickness, but it is important to realize what ill-health is costing. We have discussed the available data in Chapter XV, and shown that the total burden of ill-health probably runs into at least £300 millions a year.' P.E.P. Report, 'The British Health Services'. See also Ref. No. IA, p. 227.)

It is as though man's ignorant and greedy exploitation of the soil had put into reverse the wheel of health. Luckily there still remain on this globe one or two notable exceptions, where the law of return is still practised; where nature's cycle is whole and unbroken, and where perfect health is to be found, in crops, in livestock and in their human consumers. Some account of these beacons of light in the surrounding gloom will be given in Chapter VII.

It is a pity that it is not part of the training of every doctor to study these oases of health in a desert of sickness, in order to discover what lessons can be learnt from them, for the mere fact that they exist, and under widely differing external conditions, suggests that the birthright of man is full health.

What do we mean by health? Should we be content to define it as the military 'A.1' category? Does this definition imply 'health in the full dictionary sense of the word of wholeness, namely sound physique of every organ of the body without exception, and freedom from disease? . . . We want to know what is full health, whether the tremendous part illness and ailments play in modern civilized countries is really necessary, and if not, upon what primarily does health depend. We can ourselves attain to health--or at least with our modern skill in investigation we should be able to do so.' (G. T. Wrench, M.D. [London], *The Wheel of Health,* Daniel & Co., 1938).

Is there any evidence that we can? I think there is, and it is the second purpose of this book to present this evidence also. Those research workers who have provided it, whether they be doctors, botanists or soil specialists, have been brought, as a result of their investigations, to an acceptance of the wholeness of the cycle of life. From whatever angle these investigators may have approached the subject, and whatever disagreements they may have had with each other on the road, they appear to have arrived at the common conclusion that a close connection exists between soil fertility and health. Here their roads separate again a little. The more cautious among them give it as their considered opinion that though there are gaps in the argument, though critical scientific proof is as yet lacking at points in it, the strength of the indications is nevertheless overwhelming. Others, content to base their views on these indications backed up by circumstantial evidence, go so far as to assert their conviction that the health of man, beast, plant and soil is one indivisible whole; that the health of the soil depends on maintaining its biological balance, and that starting with a truly fertile soil, the crops grown on it, the livestock fed on those crops, and the humans fed on both, have a standard of health and a power of resisting disease and infection, from whatever cause, greatly in advance of anything ordinarily found in this country; such health as we have almost forgotten should be our natural state, so used have we become to subnormal physical fitness.

These are far-reaching claims, and it is because the implications of them are so momentous that I wish to put before you the evidence and indications on which they are based, so that, having duly considered them, you may be in a position to form your own opinion. My purpose is to present a case, but to leave the judgement to my readers. In the course of stating the case, my position will, in the main, be that of a recorder of the work and conclusions of others, but, the case once presented, there will remain two important questions still to be dealt with. In discussing these I must accept full responsibility for any views expressed.

The first is to consider means of providing irrefutable evidence. Obviously if the case holds water at all, it is a matter of the utmost urgency to devise means whereby what amounts, at present, merely to strong supporting evidence, may be converted into conclusive proof.

The second is to discuss the situation which would arise should such proof be forthcoming.

In my view, conclusive proof can only be provided by a large-scale, long-term, experiment, designed to collect the scattered evidence and reproduce it under controlled conditions in such a way that the issue shall be clear cut. The procedure for such an experiment has already been worked out, and will be described in Chapter VIII. The organization necessary to carry it out (subject to provision of the necessary financial backing) is in existence, and the foundations for it have in fact been laid.

If, when it is concluded, the results of this, or other similar experiment, were to prove beyond any reasonable doubt that health is in fact to a large degree dependent upon correct soil management, then we should be faced with a revolutionary situation, for clearly in that event, any Public Health system of the future would have to be based on soil fertility. Such a conclusion would present a formidable array of practical problems, and it is this issue which most other writers on the subject have shirked. I intend to be bold enough to walk where the more learned have feared to tread, and in the penultimate chapter I shall attempt to indicate, by what I hope are constructive suggestions, some of the ways in which, in a reconstituted, post-war world, the Government departments of Trade, Health, Food, and Agriculture should, in my view, go hand in hand to serve, instead of to exploit, the soil; to save, instead of to destroy, our citizens' birthright.

CHAPTER II
MEDICAL EVIDENCE

'Man ist was man isst'
German Proverb.

It has been announced in the press that a smaller number of people are suffering from malnutrition to-day, under wartime conditions, than was the case in the days of peace, and that the general health of the public has not deteriorated. We are rather proud of these facts, but it is not really a matter for congratulation, for it is less a tribute to our wartime organization than a grave reflection on our pre-war standards.

It has been estimated that 31½ million weeks of work are lost each year through illness, *B.M.A. Report* published by the Industrial Health Research Board. Medical Research Council.) and that we spend £185,000,000 annually on curing the sick, (See ref. No. 1B, p. 227.) a figure representing over £3 per head of the total population of the United Kingdom. Why is this necessary?

Let us turn first to the Medical Profession for an answer to this question. The Committee representing the General Practitioners of the County of Cheshire have drawn up their answer to it in a paper which they term a 'Medical Testament'. This was published in 1939, and it shall speak for itself.

MEDICAL TESTAMENT

'After more than a quarter of a century of Medical Benefit under the National Health Insurance Act we, the Local Medical and Panel Committee of Cheshire, feel that we are in a position to review our experience of the system.

'Constituted by the statute to represent the panel of an area, such a Committee is in touch with all the family doctors--in the case of Cheshire some 600--within and on its borders.

'How far has the Act fulfilled the object announced in its title--"the Prevention and Cure of Sickness"?

'Of the second item we can speak with confidence. If "postponement of the event of Death" be evidence of cure, that object has been achieved the greater expectation of life which is shewn by the figures of the Registrar General is attributable to several factors; but certainly not least to the services of the panel.

'The fall in fatality is all the more notable in view of the rise in sickness. Year by year doctors have been consulted by their patients more and more often, and the claims on the benefit funds of Societies have tended to rise.

'Of the first item, "the Prevention . . . of Sickness" it is not possible to say that the promise of the Bill has been fulfilled.

'Though to the sick man the doctor may point out the causes of his sickness, his present necessity is paramount and the moment is seldom opportune, even if not altogether too late for any essay in preventive medicine. On that first and major count the Act has done nothing. 'We feel that the fact should be faced.

'Our daily work brings us repeatedly to the same point: "this illness results from a life-time of wrong nutrition!"

'The wrong nutrition begins before life begins. "Unfit to be a mother" --from under-nutrition or nutritional anaemia--is an occasional verdict upon a maternal death. For one such fatal case there are hundreds of less severity where the frail mothers and sickly infants survive.

'The reproach of the bad teeth of English children is an old story. In 1936 out of 3,463,948 schoolchildren examined 2,425,299 needed dental treatment. Seeing that the permanent teeth develop from the 17th week of pregnancy and that certain foods, accurately known since 1918, are the condition of their proper growth, that is a reproach which should be removed. With it would go the varied host of maladies that spring from diseased teeth. That its removal is practicable is shewn by Tristan da Cunha. Most of the population of the little island, people of our race, living on the product of sea and soil, have perfect teeth which last them their lives.

'Rickets, for which England was a byword when Glisson described it in 1650, is still with us. Gross deformities are rarer, but the big heads, tumid abdomens, flaccid skins, bulged joints and pinched chests are a commonplace of infancy; and even at school age 3,457 cases of rickets with 6,415 others of spinal curvature were found in 1936 by the School Medical Officers in 1,727,031 inspections.

'Yet its prevention by right feeding is so easy that every dog breeder knows the means.

'Rickets is a heavy contributor to the C 3 population. The Maternal Mortality Committee found that there is much less in Holland where butter, milk, and cheese are plentiful and the women by virtue of their generally healthy skeletal development are protected against the risks that are commonly faced by women in the industrial areas of England.

'Nutritional anaemia is of two kinds, one subtle and apt to happen during pregnancy, the other simple and due to too little iron in the food. It is known that anaemia especially of the latter kind is common, especially among children, and women, who need much more iron in their food than men. An inquiry into the food of 1,152 families showed that 10 per cent spent 4s. a week per head on food, 10 per cent spent over 14s. whilst four more groups, of 20 per cent each, spent 6s., 8s., 10s., and

12s. respectively. The food of the three lower groups was definitely deficient in iron. It is certain from this that nutritional anaemia amongst the poorer classes is far commoner than is recognized. Here is an example: The blood colour was tested in two groups of schoolchildren, one a "routine sample" of children, the other specially selected on account of poverty. Only half the poor children and only three-quarters of the supposedly normal children had a blood colour of 70 per cent of normal.

'The final item of our indictment is constipation. Advertised aperients are a measure of its prevalence and the host of digestive disorders which result from it are a substantial proportion of the conditions for which our aid, as doctors, is sought. Yet the cause in every case--apart from rare abnormalities--is the ill choice or ill preparation of food. It is true that we are consulted on these conditions when they are established and have to deal with the effects-gall stones, appendicitis, gastric ulcer, duodenal ulcer, colitis, and diverticulitis--of years in which the body has been denied its due of this constituent of food or burdened with an excess of that. Other means of cure than proper feeding are called for at this late stage; but the primary cause none the less was wrong nutrition.

'Those four items, bad teeth, rickets, anaemia and constipation will serve as the heads of our indictment; but in truth they are only a fragment of the whole body of knowledge on food deficiencies which different investigators from Lind and Captain Cook to Hopkins and the Mellanbys have unlocked.

'But it seems to us that the master key which admits to the practical application of this knowledge as a whole has been supplied by Sir Robert McCarrison. (Major-General Sir Robert McCarrison, C.I.E., M.D., F.R.C.P.)

'His experiments afford convincing proof of the effects of food and guidance in the application of the knowledge acquired.

'In describing his experiments, which were made in India, he mentions first the many different races of which the population, 350 million, is composed.

'"Each race has its own national diet. Now the most striking thing about these races is the way in which their physique differs. Some are of splendid physique, some are of poor physique, and some are of middling physique. Why is there this difference between them? There are, of course, a number of possible causes: heredity, climate, peculiar religious and other customs and endemic diseases. But in studying the matter it became evident that these were not principal causes. The principal cause appeared to be food. For instance, there were races of which different sections came under all these influences but whose food differed. Their physique differed and the only thing that could have caused it to differ appeared to be food. The question then was how to prove that the difference in physique of different Indian races was due to food. In order to answer it I carried out an experiment on white rats to see what effect the diets of these different races would have upon them when all other things necessary for their proper nutrition were provided. The reasons for using rats in experiments of this kind are that they eat anything a man eats, they are easy to keep clean, they can be used in large numbers, their cages can be put out in the sun, the round of chemical changes on which their nutrition depends is similar to that in man, and, a year in the life of a rat is equivalent to about twenty-five years in the life of a human being. So that by using rats one gets results in a few months which it would take years to get in man. What I found in this experiment was that when young, growing rats of healthy stock were fed on diets similar to those of people whose physique was good the physique and health of the rats were good; when they were fed on the diet similar to those of people whose physique was bad the physique and health of the rats were bad; and when they were fed on diets similar to those of people whose physique was middling the physique and health of the rats were middling. . . .

"'Good or bad physique as the case might be was, therefore, due to good or bad diet, all other things being equal. Further, the best diet was one used by certain hardy, agile, vigorous and healthy races of Northern India." [Note: the Hunza, Sikh and Pathan.] "It was composed of freshly ground whole wheat flour made into cakes of unleavened bread, milk, and the products of milk (butter, curds, buttermilk), pulses (peas, beans, lentils), fresh green leaf vegetables, root vegetables (potatoes, carrots), and fruit, with meat occasionally.

"'Now in my laboratory I kept a stock of several hundred rats for breeding purposes. They lived under perfect conditions; cleanliness, roomy cages, good bedding, abundant fresh water, fresh air and sunlight--all these things they had; and, they were fed on a diet similar to that of a race whose physique was very good. They were kept in stock from birth up to the age of two years--a period equivalent to the first fifty years in the life of human beings. During this period no case of illness occurred amongst them, no death from natural causes, no maternal mortality, no infantile mortality except for an occasional accidental death. In this sheltered stock good health was secured and disease prevented by the combination of six things: fresh air, pure water, cleanliness, sunlight, comfort and good food. Human beings cannot, of course, be so sheltered as these rats were, but the experiment shows how important these things are in maintaining health.

"'The next step was to find out how much of this remarkably good health, and freedom from disease, was due to the good food: food consisting of whole wheat flour cakes, butter, milk, fresh green vegetables, sprouted pulses, carrots and occasionally meat with bone to keep the teeth in order. So I cut out the milk and milk products from their diet or reduced them to a minimum, as well as reducing the consumption of fresh vegetable foods while leaving all other conditions the same. What was the result? Lung diseases, stomach diseases, bowel diseases, kidney and bladder diseases made their appearance. It was apparent, therefore, that the good health depended on the good diet more than on anything else and that the diet was only health-promoting so long as it was consumed in its entirety, so long, in fact, as it contained enough milk, butter, and fresh vegetables.

"'Many more experiments were done which showed that when rats or other animals were fed on improperly constituted diets, such as are habitually used by some human beings, they developed many of the diseases from which these human beings tend to suffer: diseases of the bony framework of the body, of the skin covering it and of the membranes lining its cavities and passages; diseases of the glands whose products control its growth, regulate its processes and enable it to reproduce itself; diseases of those highly specialized mechanisms--the gastro-intestinal tract and lungs--designed for its nourishment; diseases of the nerves. All these were produced in animals under experimental conditions by feeding them on faulty human diets. Here is an example of such an experiment: Two groups of young rats, of the same age, were confined in two large cages of the same size. Everything was the same for each group except food. One group was fed on a good diet, similar to that of a Northern Indian race whose physique and health were good, and of which the composition is given above. The other was fed on a diet in common use by many people in this country; a diet consisting of white bread and margarine, tinned meat, vegetables boiled with soda, cheap tinned jam, tea, sugar and a little milk: a diet which does not contain enough milk, milk products, green leaf vegetables and wholemeal bread for proper nutrition. This is what happened. The rats fed on the good diet grew well, there was little disease amongst them and they lived happily together. Those fed on the bad diet did not grow well, many became ill and they lived unhappily together; so much so that by the sixtieth day of the experiment the stronger ones amongst them began to kill and eat the weaker, so that I had to separate them. The diseases from which they suffered were of three chief kinds: diseases of the lungs, diseases of the stomach and intestines, and diseases of the nerves; diseases from which one in every three sick persons, among the insured classes, in England and Wales, suffer."

'These researches were minutely made on a large scale and, but for the food, the conditions of each group were identical and ideal. Their results to our minds carry complete conviction--especially as those of us who have been able to profit by their lesson have been amazed at the benefit conferred upon patients who have adopted the revised dietary to which that lesson points. (See Chapter VI.)

'It is far from the purpose of this statement to advocate a particular diet. The Eskimos, on flesh, liver, blubber and fish, the Hunza or Sikh, on wheaten chappattis, fruit, milk, sprouted legumes and a little meat; the islander of Tristan on his potatoes, seabirds' eggs, fish and cabbage, are equally healthy and free from disease.

'But there is some principle or quality in these diets which is absent from, or deficient in, the food of our people to-day. Our purpose is to point to this fact and to suggest the necessity of remedying the defect.

'To descry some factors common to all these diets is difficult and an attempt to do so may be misleading since knowledge of what those factors are is still far from complete; but this at least may be said, that the food is, for the most part, fresh from its source, little altered by preparation and complete; and that, in the case of those based on agriculture, the natural cycle

is complete.

'No chemical or substitution stage intervenes.

'Sir Albert Howard's work on the nutrition of plants, initiated at Indore and carried from India to many parts of the world, seems to constitute a natural link in this cycle. (Sir Albert Howard, C.I.E., M.A. See next chapter.)

'He has shewn that the ancient Chinese method of returning to the soil, after treatment, the whole of the animal and vegetable refuse which is produced in the activities of a community results in the health and productivity of crops and of the animals and men who feed thereon. . . .

Though we bear no direct responsibility for such problems, yet the better manuring of the home land so as to bring an ample succession of fresh food crops to the tables of our people, the arrest of the present exhaustion of the soil and the restoration and permanent maintenance of its fertility concern us very closely. For nutrition and the quality of food are the paramount factors in fitness. No health campaign can succeed unless the materials of which the bodies are built are sound. At present they are not.

'Probably half our work is wasted, since our patients are so fed from the cradle, indeed before the cradle, that they are certain contributions to a C 3 nation. Even our country people share the white bread, tinned salmon, dried milk regime. Against this the efforts of the doctor resemble those of Sisiphus.

'This is our medical testament, given to all whom it may concernand whom does it not concern?

'We are not specialists, nor scientists, nor agriculturists. We represent the family doctors of a great county, the county, said Michael Drayton, of "such as soundly feed"; a county which gives its name to a cheese than which there is none better, though to most Englishmen, alas, only a name; a county where the best farming is still possible, which should minister to the needs of its own industrial areas and of a far wider circle.

'We cannot do more than point to the means of health. Their production and supply is not our function. We are called upon to cure sickness. We conceive it to be our duty in the present state of knowledge to point out that much, perhaps most, of this sickness is preventable and would be prevented by the right feeding of our people. We consider this opinion so important that this document is drawn up in an endeavour to express it and to make it public.'

(Signed by the Members of the Local Medical and Panel Committees).
JOHN KERR (*Chairman*).
N. A. BOSWELL (Vice-Chairman).
J. BARRY BENNETT (*Hon. Treasurer*).
LIONEL JAS. PICTON (*Hon. Secretary*).

I think you will agree that this is an impressive document deserving of a far wider publicity than it has received. It lends point to the classic German pun which heads this chapter: 'man is what man eats'.

Let me repeat the opening sentences of the major indictment of this remarkable testimony: 'The fall in fatality is all the more notable in view of the rise in sickness. Year by year doctors have been consulted by their patients more and more often, and the claims on the benefit funds of Societies have tended to rise. . . . On that first and major count (prevention) the Act has done nothing.'

This suggests that our national health is deteriorating; yet other authorities have published statistics to show that it is on the contrary very much better than it used to be. How can these two views be reconciled?

The following medical opinion, which is widely held, contains the answer, I think: 'The infective diseases are under far better control, but degenerative diseases--such as blood pressure diseases, heart diseases, rheumatism, diabetes, nervous disease, kidney disease, gastro-intestinal disease, cancer and mental disease--which impair the prime of life, or what should be the prime of life, are admittedly more prevalent.'

Lord Portsmouth, in his book *Famine in England,* (Witherby Ltd.) published in 1938, wrote, 'Dr. Howard Mummery, Chairman of the Association of Industrial Medical Officers, revealed the other day that workers insured under the National Health Insurance Act lost on an average twenty-eight days of work a year through illness, compared with 16.5 days of work fifteen years ago.' (G. C. Anderson, Secretary of the British Medical Association, writing to the *Daily Telegraph* on 5th February 1943 stated that over 50 per cent of registered panel patients attend, or are attended by their doctors in the course of a year.) This would seem to support the view that ill health is increasing.

Some part of this increase may indeed be due to the adoption of a different standard of 'disablement', and a greater readiness to consult a doctor. But this in itself points to a significant preoccupation with bodily states, a diminished power of resisting and throwing off incipient ailments. Certainly it does not suggest any advance in the prevention of sickness commensurate with advances in medical knowledge, Public Health services, housing and sanitation. That this view is shared by members of the Medical Profession in the United States of America, where health services are unsurpassed, is shown by the two following quotations

'Great gains in health have been achieved since the beginning of this century. Tuberculosis is being vanquished. Deaths from infantile diarrhoea, diphtheria, typhoid fever, etc., are being eliminated. All diseases of bacterial origin have decreased in a striking manner. The average length of life--that is, the expectation of life at birth-was only forty-nine in 1900. To-day it has gained more than eleven years.

'The chances of survival for each age up to maturity have notably augmented. Nevertheless, in spite of the triumphs of medical science, the problem of disease is very far from solved.

'Modern man is delicate. Eleven hundred thousand persons have to attend the medical needs of 120,000,000 other persons.

'Every year, among this population of the United States, there are about 100,000,000 illnesses, serious or slight. In the hospitals 700,000 beds are occupied every day in the year. The care of these patients requires the efforts of 145,000 doctors, 280,000 nurses or student nurses, 60,000 dentists, and 150,000 pharmacists. It also necessitates 7,000 hospitals, 8,000 clinics, and 60,000 pharmacies.

'The public spends annually £143,000,000 in medicines. Medical care, under all its forms, costs about £700,000,000 yearly.

'Obviously, disease is still a heavy economic burden. Its importance in modern life is incalculable. (Dr. Alexis Carrel, *Man the Unknown,* p. 114, Hamilton, 1935).

'Although it is true that our life span has been increased, yet an analysis of that gain shows it is confined almost entirely to lower age groups. Excluding infant mortality and the diseases of childhood, and excepting also our control of the major pestilences the chances of dying after you reach thirty-five are about as great to-day as they were a hundred years ago. The human race still digs its own grave with its teeth. The man who said this probably uttered one of the greatest truths. Until recently we did not know that disease could be absolutely proved to be intimately connected with diet. . . .

'Working hard when you are young and earning a competence on which you can retire and enjoy yourself sometime after you are fifty will bring you little happiness if you are not well enough to enjoy those years. Most of the diseases which we associate with this period are the direct results of an improper diet in youth.' (Victor Heiser, M.D., *You're the Doctor.* Jonathan Cape, London, 1939).

Bearing this last point in mind, let us now examine in rather more detail the evidence of the Rats of Coonoor. Dr. Wrench in his book *The Wheel of Health* discusses the results of McCarrison's experiments at some length. His observations seem to me important, and at the risk of some repetition I must now record part of what he has to say:

'In 1921 Sir Gowland Hopkins had made public his work on accessory food factors, to which Casimir Funk a year later gave the name of vitamins. McCarrison, reading the work, at once thought that maybe a very important clue to the enigma of goitre lay in a deficiency of vitamins in the food which goitrous people eat. So he began experiments in the Kasauli laboratory designed to give pigeons goitre. He fed them on diets defective in vitamins. Something different happened. The birds did not develop goitre but some of them, as was expected, developed a disease called polyneuritis. Then it was found that these birds were overrun by specific microbes. Now came the surprise. Some of the healthy birds, the stock of the laboratory who were well fed before any experiments were tried upon them also harboured these microbes, but they were not ill. The ill-fed birds, on the other hand, were mortally sick. If, however, the healthy birds were fed on the food defective in vitamins, they too got the polyneuritis and died. Good feeding, it seemed, protected the birds against the microbes, but faulty feeding led to a microbic triumph. Thus was McCarrison brought into a field of "deficiency diseases", that is to say, diseases due definitely to faulty food.'

The rat experiments described in the Medical Testament were undertaken (after McCarrison's appointment in 1927 as Director of Nutrition Research in India) at his laboratory and headquarters at Coonoor. In the first experiment, in which he transferred the exceptional health of the Hunza, Sikh, and Pathan to his rats, 1,189 were fed on the diets of these healthy peoples, and watched from birth to the twenty-seventh month, the age which, you will remember, corresponds to that of about fifty-five years in the life of man.

Describing the results, in a lecture given at the College of Surgeons in 1931, McCarrison told how throughout the course of this two and a quarter years he had been unable to discover any case of illness in this 'universe' of albino rats, either clinically, or at post-mortem examination. Wrench commenting on this result writes:

'Now the reader might think that a statement that any small "universe" had been freed from disease would have created a profound impression amongst medical men. It did not do so, any more than Lister's announcement of the first results of antiseptic surgery created any stir. In Lister's days surgeons were so accustomed to pus and blood poisoning, they could not think in terms of surgery without them. Similarly, medical men are so accustomed to a great number of diseases, they cannot think of any small "universe" without disease. In all revoluions this is the case. It is the established profession, or class, or aristocracy, which finds it most difficult to think in terms of the change. 'This is very noticeable in the professional comments of that time upon McCarrison's lectures. Actually they were very meagre. . . . The British Medical Journal . . . did, however, devote a leading article. This article treated McCarrison's work purely from the point of view of diseases which diet would prevent or help to prevent. It overlooked the astonishing relation of a remarkable health of human groups being transferred to rats as a perfect health. . . . The health was transferred by foods. . . . The only thing . . . that was common to rat and man in this first experiment was the diet. Here in the great cleft of Hunza was a little oasis of a few thousand beings of almost perfect health, (See Chapter VII) and here in the cages of Coonoor was a little oasis of a thousand and more albino rats also in perfect health. The only link connection between these two otherwise dissimilar sets of living things was a similar kind of diet.'

In subsequent experiments, as recounted in the Medical Testament, the rats were linked to other Indian peoples by their diet. In every case the average standard of health of a given human group was faithfully mirrored in the rats, including the percentage incidence of specific diseases. Nor was this reflection confined to bodily ailments, for neurasthenia, and bad-temper, you will remember, showed themselves in the rats fed on the common English diet. During the course of this series of experiments, McCarrison found, and listed, diseases of every organ of the body among the 2,243 rats fed on faulty Indian diets. (For complete list see Technical Ref. No. 2)'Considering . . . the simplicity of the rat, and its limitation in things human,' writes Wrench, 'the list is, comparatively speaking, almost as complete as the list of contents of a stately text-book of medicine. "All these conditions," said McCarrison, "these states of ill-health had a common causation; faulty nutrition with or without infection."'

Sir John Orr, writing about these experiments (*Food, Health and Income,* 1936) points out that 'such experiments with rats, of course, do not carry the same weight as observations on human beings'. Wrench, discussing this point, writes:

'This criticism is particularly interesting because it follows, not only a brief précis of McCarrison's work, but also one of a valuable, similar and later experiment of Orr's upon rats fed upon "the average diet eaten by a working-class community in Scotland (with its) daily variation, thus mimicking the food habits of human beings". There was, however, a small addition to the quantities of milk, as rats could not be bred without the larger allowance (*Journal of Hygiene,* Vol. 35). The results were in the main similar to those of McCarrison.

'Now, the noticeable thing about this criticism is that Orr fragments the experiments of both McCarrison and himself. He separates the experiments upon rats from the observations on human beings.

'In actual fact McCarrison's experiments were preceded by, and due to, observations upon human beings. The men were observed first and then the rats. Orr's experiments were due to the example of McCarrison and observations of the unsatisfactory state of the Scotch working-class. Ill-health was transferred to rats by men's faulty food. Without the observations on man the experiments would never have been undertaken.

'The criticism shows the hold fragmentation has upon the mental habits of scientists. Orr no sooner reaches McCarrison's truth by his own experiment than he separates himself from it owing to this habit.

'A further comment might be made, namely, that the food would never have had such a full effect if the healthy rats had not been cleanly and airily housed and enjoyed sheltered lives, even though these conditions were also those of the sickly rats.

'Air, or rather oxygen, it can rightly be maintained is a part of the food. When the human being is in the womb, oxygen is not separated in any way from the other elements of food, but is brought with them by the mother's blood. It remains a food after birth, but it has peculiar importance in assisting at so many vital processes of movement and energy that it has constantly to be sprayed into the blood by the special apparatus of the lungs.

'Hence the airy cages of the rats of Coonoor were a healthy asset, but that is all. They did not save the sickly rats. . . .

'The inescapable conclusion is that in a very large number of diseases faulty food is the primary cause. The suspicion is that faulty food is the primary cause of such an overwhelming mass of disease that it may prove to be simply *the primary cause of disease.*

'Up to the present day, it seems, the medical profession and the public have had to be satisfied with a fragmentation of causation, that is to say, a very great number of secondary causes and often enough no real causes at all., but causes as fictitious as they are popular.

'For the purposes of illustrating and emphasizing the really immeasurable importance of this contrast, if correct, let us take some few of these illnesses and put their causes as given in medical text-books and as shown by the rats of Coonoor in parallel columns.

'Let us first take that dangerous disease, pneumonia. Pneumonia is due to a microbe, the pneumococcus, which is found in masses in the lung in true lobar pneumonia. The pneumococcus, says the text-book, is a resident of the human mouth. It is found in 80 to 90 per cent of normal healthy individuals. Something more, then, than the mere presence of the pneumococcus must be the cause of pneumonia; something that makes this domesticated microbe suddenly become dangerous. In other words, the pneumococcus cannot be called the primal cause of pneumonia. Something has to precede it-some weakness of the barrier.

'The weakness of old age is given first of the orthodox causes in the text-book. . . .

'Pneumonia is more common in cities than in the country and in males than in females. Any weakening habit, such as that of over-drinking, becomes a cause, and also makes the microbes more lethal. Yet robust men may be attacked. Cold is a cause if it weakens, but not if a man finds it a tonic and reacts to it. A previous attack makes a second attack more probable. Another illness, such as chronic kidney or heart disease or one of the acute infectious fevers, gives opportunity to the pneumococcus. So also pneumonia may follow a blow on the chest.

'Now let us place these causes from text-books in juxtaposition with that of the "small universe" of Coonoor.

CAUSES OF PNEUMONIA

Text-books	*Coonoor*
Weakness of old age.	Faulty Food.
Debilitating habits.	
Exhaustion.	
Chill.	
Previous attack.	
Some other illness, chronic or acute.	
A blow on the chest.	
Pneumococcus microbe.	

'. . . Summing up the text-books' causes, one may call them a number of added weaknesses to an inferior barrier against disease. The barrier gives way readily at this or that point. In other words the barrier has degenerated.

'By his skilled science man is actually able to get a partial picture of what this barrier is. It is in fact an actual barrier. It can be seen through the microscope. It can be seen if it looks healthy or degenerate. It can be photographed, and the photograph of a healthy barrier has clear outlines and demarcations and that of a degenerate barrier is blurry. This barrier is the fine skin which lines the tubes and cells of the nose, windpipe and bronchial tubes, of the mouth, throat, stomach and small and large gut. The fine interior skin is much the same as the outer skin of the body, only it is thinner and softer. But both have an outer layer of cells called epithelium, and it is the epithelium that can be particularly well seen under the microscope. It is the epithelium that forms the visible barrier and which shuts out microbes and other intruders. It does not by any means form the whole barrier, but it constitutes a part of it, which can be seen as clear and definite or blurred and indefinite, according to whether it is itself well or ill fed. The contrast picture gives anyone with even a little knowledge of the microscope a good idea of what can be termed the barrier or, more accurately, the first line of defence. It is not fiction.

'So we can understand how it is that faulty food can stand alone under the heading Coonoor against the juxtaposed text-books' list of the causes of pneumonia. It can be placed there as primary, and thereby able to make all the causes in the text-books possible; it can activate them. Without it they would be inert.

'Now let us look at the common infection of the middle ear. Mellanby found this infection in a fifth of his faultily fed rats. It was common among the ill-fed rats of Coonoor, but absent in the well-fed. On the other hand, a well-known text-book, such as Politzer's Diseases of the Ear, does not mention faulty food as a cause, any more than faulty food was mentioned under pneumonia. That the whole basis of modern life may be wrong and that that is why such large text-books have to be written has not as yet appeared in the text-books themselves.

'Putting the causes of acute infection of the middle ear into juxtaposed columns, we have:

Text-books	*Coonoor*
External atmospheric conditions.	Faulty Food.
Colds in the head.	
Infectious diseases, such as measles pneumonia and influenza.	
Sea baths.	
Nasal douches.	

'There must be therefore, in faultily fed people, a fear of cold night air, colds in the head; other people coughing and sneezing; schools where children mingle with children; bathing in the sea; and keeping off the "flu" by snuffing lotions or using nasal douches, as recommended by advertisers. Any of these things may lead to passing of the barrier and the defences of the tissues of the ear.

'The eyes are even more commonly affected by faulty food than the ears. The sickly rats of Coonoor got inflammations of the eyes, ulcers, and a particular "dry" eye leading to blindness. All of these the well-fed rats escaped.

'The text-books all accept defective food as a cause of "dry" eye of it if not too far advanced. With this exception there is no direct reference to faulty food as a cause of diseases of the eye. There is only the general statement that these diseases are more common among the poor and debilitated.

'A medico-surgical disease which is of particular interest is peptic ulcer, or ulcer of the stomach or duodenum. It is of particular interest because of its proven direct relation to faulty food. It happens to be very common amongst the poorer classes of Southern Travancore--so common that both Lt.-Col. Bradfield, I.M.S., and Dr. Somervell asked McCarrison to put rats on the foods as prepared and eaten by these people. (This contains a high proportion of tapioca.) He put a batch of rats on the food as prepared and cooked by the poorer folk of Southern Travancore for 675 days, and at the end of that time peptic ulcer was found in over a quarter of them.

'This striking result has not yet appeared in the text-books. As is the way of new knowledge, it passes into currency by a process of slow percolation. Until the time comes when it reaches the text-books the causes of peptic ulcer placed in juxtaposition, appear as follows:

CAUSES OF PEPTIC ULCER

Text-books	*Coonoor*
Occupation: anaemic and dyspeptic servant girls, shoe-makers, surgeons.	Primarily faulty food.
Injury.	Specifically such food as that of the poorer classes of Southern Travancore.
Associated disease such as anaemia, heart disease, disease of liver, appendix, gall bladder, teeth, tonsils.	
Nervous strain.	
Disturbances of the circulation.	
Large superficial burns.	
Certain families are said to be more liable.	
Increased acidity of the stomach.	
Several of the above in combination.	

'The last disease I propose to take in these few illustrations is tuberculosis. As regards this dreaded disease, McCarrison, in the Cantor Lectures, turned from his own work to one of the most remarkable of human experiments, that of the Papworth Settlement, so intimately associated with the name of Sir Pendrill Varrier-Jones.

'Papworth is a settlement for sufferers from tuberculosis, mostly in the form of consumption of the lungs. The patients are, of course, ill when they come to the settlement, but under a care, really quite like that given to the rats of Coonoor, namely adequate food supply, good housing, and ventilation and freedom from anxiety in the form of loss of employment, there are remarkable and sustained recoveries.

'All patients at Papworth have sputum pots and pocket flasks into which they must spit. The infected sputum is at once made innocuous. Moreover, public opinion in the village enforces their use by attaching shame, not to the users, but to those who dare to be forgetful.

'In Papworth there are many married couples. The children of these couples live in the settlement. They are in frequent contact with tuberculosis and are protected from the disease by the general use of the spitting pots and flasks and by good food, or in Varrier-Jones's own words "the child's resistance to disease is maintained by
(*a*) adequate nutrition, and
(*b*) the absence of mass dose of infection."

'Now comes the outstanding fact. The Papworth village has been in existence twenty years, yet not one of the children of these married couples has developed any form of tuberculosis. "Our experience proves", writes Sir Pendrill in his report for 1936, "that no tuberculosis disease need be transmitted so long as village settlement conditions of housing and employment are properly utilized. Any question of 'heredity' is now generally discredited."

'In face of this testimony to the power of resistance to tuberculosis given by good food and housing, and with spitting pots to avoid mass infection, the text-books put forward "pre-disposition" as a widely accepted medical tenet. . . .

'This terrible Calvinistic doctrine, by which certain people, and particularly artisans of the cities, are born predestined to get tuberculosis has therefore been challenged by the good food, security, and the avoidance of mass infection at Papworth.

'The Papworth results suggest the following juxtaposition

CAUSES OF TUBERCULOSIS

Text-books	*Papworth*
Infection with tubercle bacilli.	Inadequate nutrition.
Inherited predisposition.	Mass dose of infection.
Living in dark, close alleys, and tenement houses, excess of alcohol and other weakening habits.	
Confinement in prisons, workhouses and workshops.	
Catarrh of respiratory passages.	
Diabetes, kidney disease and other chronic affections which lower resistance.	

'If the list of the text-book is carefully examined we see how the causes there given are all, except that of diathesis, to be found contained in the two Papworth causes. Infection with the tubercle bacilli in the one column is duplicated by the mass infection of the other. Frequent inhalation of quantities of the microbes gives greater opportunities to them to breach the barriers. All the rest are the fragmentation of "inadequate nutrition".

'Living in dark, close alleys and tenements means also faulty food. The impure air of slums means one food, namely, oxygen, being defective, but it means also that people who breathe it have not the money for foods that cannot, like oxygen, be got for nothing. Alcohol in excess destroys the appetite. So do the poisons of such diseases as diabetes and kidney disease. So does confinement in prisons, workhouses, and workshops. None of the people debilitated by such places or such diseases eat heartily of good food. As to catarrh of the respiratory passages, that in itself was produced by McCarrison and also by Mellanby by faulty food. The barrier breaks down before the catarrhal microbes. A mass attack of tubercle bacilli may do the rest.

'If then, one can put aside the predestination theory of tuberculosis, there lies one thing behind all the other causes given, and that is faulty food and, moreover, as we shall see, faulty food may account for the apparent predestination.

'Fortunately there is another triumph in establishing the general cause of many diseases and ill-health in poor English children. With just as unpromising human material as that of the Papworth children the late Miss Margaret McMillan gained this success, which is described in her book *The Nursery School* (1930).'

This is an open air school in Deptford, and the children are drawn from the surrounding slums. It is on a sufficiently large scale for the results to have critical importance. During the years described in Miss McMillan's book, it consisted of two hundred and sixty children from the ages of two to five, of which eighty continued under her care, until they reached the age of fourteen or fifteen. Dr. Wrench does not minimize the importance of the all round care devoted to these children, but obviously regards 'well considered food' as being one of the most important factors in the truly remarkable results achieved. 'Next door to the school,' he writes, 'is "our own" Deptford Clinic for sick children. School and clinic under that one authority present themselves as human replicas of the rats of Coonoor.

'Here is Miss McMillan's description of the food of the school. "Out all day in moving air, children are always hungry at meal-times, but no food is given between meals. In summer they have fruit from the old mulberry-tree, and we give small spoonfuls of orange juice. Fruit and fresh vegetables are needed by everyone, but especially by growing children, and most of all by children of the poorest classes in cities. Their bones are literally starved of mineral salts. They suffer from starvation in the way of nitrogenous food and of all that nature supplies in green food and fruits. Bread, bread, and always bread in surfeit is their portion. Our fresh vegetables, meal and milk work wonders."

'The test of a diet is the wholeness of those who eat it. This is the description of the children of seven, after four years spent in the school "They are all straight, well-grown children, alert, sociable, eager for life and new experience. . . . The abyss between him and the child of yesterday yawns deepest, perhaps when we compare the state rather than the achievements of the nurtured child with that of the other. The nurtured seven-year-old is a stranger to clinics; he knows little about doctors. He sees the dentist, but hardly ever, or perhaps never, needed any dental treatment."

'To "our clinic" come the sick children of Deptford. They are just ordinary poor children who go to other schools and have other homes than hers. They present the picture of the sickly rats of Coonoor; Miss McMillan draws the contrast, though not in juxtaposed columns.

'"There, ranged on seats by the walls, sit scores of sufferers. Blepharitis, impetigo, conjunctivitis, skin diseases of many kinds, these are not seen in our school. They are seen in the clinic-thousands of cases all preventable." There follow further illnesses seen in the clinic-adenoids, bad tonsils, colds, coughs, bronchitis,enlarged glands, gastric and intestinal troubles-in short, the list which afflicted the sickly rats of Coonoor.

'Now both Sir Pendrill Varrier-Jones and Miss McMillan have been exceptionally imaginative in seeing that *all* the conditions of life in those under their care were made wholesome, things of the mind as well as those of the body, and it is to this wholeness that they attribute the health of their wards. They do not select food as the primary cause of the health. They regard the whole as resulting in health.

'This is so reasonable that I think no one reading their results would care to diminish any one guard of healthy life which they have erected, such as modern housing and hygiene.

'Yet, apart from proofs and arguments already put forward to maintain the vital primary claim of food, there is one very exquisite human experiment made by Dr. G. C. M. M'Gonigle, Medical Officer of Health of Stockton-on-Tees, which strengthens this claim in a manner that may be called one of accidental finality.

'Stockton-on-Tees is an ancient market town which has grown rapidly in the last three-quarters of a century and now has a population of 67,722 (1931). Of this population in that year 40 per cent of the males between fourteen and sixty-five were unemployed.

'Stockton has slums, and the Town Council recently carried out a vigorous policy of better housing. It was this that gave M'Gonigle an opportunity to exercise his excellent powers of scientific observation.

'A survey of housing needs was taken in 1919, and the largest section of the town scheduled as an unhealthy area was dubbed "Number 1 area". It was decided to demolish a part of Number 1 and transfer its inhabitants to a new up-to-date municipal estate, agreeably named Mount Pleasant. In 1927, 153 families, comprising 710 individuals, were transferred to Mount Pleasant, leaving behind in Number 1 area 289 families with a total of 1,298 individuals.

'Here, then, were contrasting conditions of new and old, of good housing and slum. Naturally everyone thought the transfer to Mount Pleasant would be a betterment. But M'Gonigle watched.

'Even he, however, watched at first according to the routine of his official position. It was only when he found that something odd was happening and the expected success was not coming off, that he concentrated a keen and skilled observation upon the anomaly.

'His attention was drawn to it by the fact that the health of the inhabitants of Mount Pleasant, instead of improving or at least remaining stationary, began to deteriorate, whereas that of those families and people left behind in the slums did not.

'M'Gonigle then began to test out what was happening statistically. The standardized death-rate of the first five years following upon the transfer was 33 per 1,000; that of the unchanged slum 22 per thousand. The rate for the Mount Pleasant estate of "3355 per thousand, appears to be extraordinary, in view of the fact that it represents an increase of 46 per cent over the mean standardized rates for the same individuals in the previous quinquennium," is M'Gonigle's comment. The increase was not due to any peculiarity of infant mortality, epidemic, or other recognized cause. It was just there steadily throughout, and it represented an increase in the various groups, from 0 to 10, between 10 and 65, and over 65. It was a characteristic of the whole people of Mount Pleasant. It was "a real increase and beyond the probable extent of fortuitous variation".

'What was it due to? The better housing? It seems absurd that something better should prove something worse. Yet, in spite of the best intentions, this happens if primary things are forgotten. Man lives primarily by food, not by housing, and the food of the Mount Pleasant people was what had deteriorated.

'When living in the slums these people paid rents which averaged 4s. 8d. a week per family. In 1928, on the Mount estate, the rent was 9s. a week, and by 1932 it had risen to 9s. 3½d. per week, or double the original rent.

'Consequently there was less money to spend on food.

'M'Gonigle worked out the average amount spent on food per individual for Mount Pleasant and for slum by carefully prepared and corrected statistics. It is obvious, in view of the different rents paid, that Mount Pleasant was worse off. Particularly was this shown in the case of unemployed of both areas. The food per "man" per week at Mount Pleasant cost 34.7 pence, that in the unchanged slum 45.6 pence.

'M'Gonigle was, therefore, forced to the conclusion that the deterioration of food led to the deterioration of health. "Such environmental factors as housing, drainage, overcrowding or insanitary conditions" could obviously be excluded. These secondary factors were not worse at Mount Pleasant. They were a great deal better. That was the good fortune of this illuminating experiment. The secondary things, namely, housing and sanitation, were made better first, and in making them better money was withdrawn from the individual's primary need-food.

'The experiment emerges as an example of putting the building of new houses and of organizing physical drill on a par or as prior to food in policy of health. They are both good things, but they are not primary.

'Muscular energy and activity follow right feeding naturally, and physical training can follow upon the muscular energy. No one indeed disputes this proposition--except in their acts and public policies. There is a general, rather indefinite feeling that sound food is the primary cause of health, but when this shapes itself out of the mist, there appear secondary, not primary forms--good housing, hygiene, physical drill.

'M'Gonigle showed that food took the primary place to good housing and sanitation.'

I would ask you specially to note this last point in view of the number of prominent people who to-day give housing first place in their plans for reconstruction.

CHAPTER III
HUMUS

'All destructions ordered by God are mere
quarryings of His building materials.'
Abbott Vonier.

If 'faulty food' is the correct reply to our question, 'Why so much sickness?'--if we are, in fact, what we eat--then the logical next question is: 'What is the matter with our food?' For while it seems clear that much of the blame must rest on our often ill-chosen diet, the complete answer must go deeper than this. In the U.S.A., for example, a very great deal of attention is paid to the proper balancing of diet, and milk, green leaf vegetables, and raw salads (McCarrison's 'health foods') are eaten in large quantities, yet America's '100 million illnesses a year' does not suggest that her people are markedly healthier than we are on that account. Dr. Alexis Carrel states that 'modern man is delicate'. If the primary cause of this decline in vigour is faulty nutrition, then the natural conclusion is that there must be something lacking in the quality of our foods themselves; something which was not lacking in the foods of our more robust forefathers.

In this chapter I shall present the evidence supporting the view that this conclusion is correct. Some part of this deterioration in food is, indeed, readily demonstrable and is due to the commercial development of 'processed food' wherever this has involved submitting it to treatment which profoundly alters its bio-chemical constitution.

The case of white flour is an outstanding example of such alteration. In removing the germ, modern methods of milling have removed those parts of the wheat berry which contain the vitamins B and E, a removal which, until the introduction of the National loaf and except for a brief period during the last war, has been complete since 1872. The everyday results of this are well illustrated in the following anecdote from Adrian Bell's *Men of the Fields.*

'I found a man of over seventy cutting up a fallen tree. . . . He used a curious phrase to justify the conditions under which the men of his father's generation had worked. "Well, they had their life," he said. "Mind you, I couldn't work to-day like they worked--not if I was young, l couldn't work like I worked as a young man. The bread to-day hasn't got the stay in it. I know, because I've worked on it. When I used to go to work and we baked at home, when I'd had my breakfast that'd stay by me to dinner-time. But when we took to bakers' bread, why, after you'd worked for an hour that'd be gone and you'd feel faint inside."'

Expressed in more scientific language:

The introduction of steel roller mills nearly seventy years ago has 'resulted in the reduction of the nutritive value of the protein, in serious lowering of the content of calcium, phosphorus and iron, in reduction of the vitamin B_1, and vitamin B_2 complex content, and probably in complete removal of the vitamin E, all representing dead loss nutritionally.' (A. M. Copping, 'The Nutritive Value of Wheaten Flour and Bread', *Nutrition Abstract and Reviews*, 1939).

When it is remembered that B_1 is the vitamin essential to the proper nourishment of nervous tissue, and that vitamin E plays an important part in reproduction and probably also in general vigour, there is cause for reflection upon the increase of nervous disorders and the falling birth-rate in the present generation. May not these conditions, too, be attributable to faulty diet?

It is generally admitted that wheat germ oil is one of the richest known sources of fertility. It is widely used in both human and animal medicine in the treatment of sterility. ('In 1932 Vogt Muller treated 20 sterile women with an extract of wheat germ oil, and 17 of them had living children. Dr. Currie, of Leeds, in 1936 related success in curing habitual abortion, while in 1940 C. G. Collins (*et al.*) cured 21 out of 25 similar patients. In both series of cases wheat germ oil was the main factor in the cure.' Quoted from letter to *The Times,* 1st May 1942, by L. J. Picton, O.B.E., B.A., B.M.) Its restoration to our national loaf may well benefit the nation in more ways than in the mere saving of shipping space. (The rise in the birthrate for 1942 is significant in this connection.)

Further possible evils resulting from food processing are suggested by Dr. F. J. Poynton, who, writing in the *British Medical Journal* of 21st October 1933, records his opinion that infantile scurvy is on the increase. He reports no less than three cases at one time in his ward at the Great Ormond Street Hospital for children.

'This seems remarkable,' he writes, 'when we realize the great work that has been done on vitamins, and when we look upon the position of Vitamin C as one of the best understood among them.' Discussing the possible causes of present-day infantile scurvy, he writes: 'I am not prepared to do more than direct attention to the vast quantities of dried milk now in use and to raise a question which I have raised before, whether such foods even given with precautions, make for the best constitutions in years to come. We know that some children do not take to fruit juices well, or are thought not to take them well, and these are then discarded; and should infantile scurvy really be on the increase, and my experience not be only a hospital coincidence, it is clear to me that many diets must touch the border line of a pathological metabolism.'

'Note. The insecurity of reliance upon orange juice to correct the damage done to milk by heating it (pasteurizing, boiling, or drying) is rendered more obvious by the common use of cold storage for oranges, as, according to Professor Plimmer, vitamin C is slowly destroyed by freezing.' (Quoted from the References to the Medical Testament.)

'Dr. Evelyn Sprawson, London Hospital, stated that children in the institution in which he worked who were fed on raw milk had perfect teeth, whereas others in circumstances identical in all, respects except that their milk was pasteurized, had defective teeth.' (Quoted from the References to the Medical Testament.)

This is a point worth underlining in view of the present agitation in favour of compulsory pasteurization. (For a brief discussion of the pros and cons of this controversial topic see Technical Ref. No. 3.) There would appear to be some, as yet undefined, harm done to foods by long storage of any kind, whether frozen, heated and tinned, or dried (probably least by drying). McCarrison states

'There is something in *freshness* and *quality* of foods which is not accounted for by the known chemical ingredients of food: proteins, fats, carbohydrates, minerals and vitamins.' (Quoted from the References to the Medical Testament.)

'It is certain that this "something" plays a part in that perfect combination of eye, muscle, nerve, blood-vessels and endocrines, which enables the heron to avoid the hawk; and in that other protective equipment-serenity and courage, clean blood plasma, and lively reticuloendothelial system-which wards off infection and constitutes a natural active immunity.' (L. J. Picton, O.B.E., M.A., M.B.,'The Problem of Natural Food', *Medical Press and Circular,* 8th November 1939).

Systems of processing and storage, however, are not the only factors responsible for deterioration in the vital quality of human food, for these foods themselves, when in the living state, show a decline in resistance to ailments; a lowered 'quality' and vigour exactly parallel to that found in the human race.

The loss to the livestock industry caused by such complaints as mastitis, contagious abortion, Johne's disease, foot-and-mouth disease, swine fever, swine erysipelas and white scour--to mention only a few--runs into millions of pounds annually and is on the increase. I well remember, for example, that when I was an agricultural student in 1915 we were told by our lecturer on animal hygiene that foot-and-mouth disease need not concern us, since the disease was obsolete in this country. It is commonly held that the prevalence of foot-and-mouth in the last decade is due to imported meat. Col. G. P. Pollitt, in his little book *Britain Can Feed Herself,* Macmillan & Co., 1942, expresses this view. 'The repeated outbreaks in this country,' he states, 'are primarily, if not wholly, due to our imports of uncooked meat.' I find this explanation unconvincing; the imports of meat into this country in 1913, shortly before the disease was said to be obsolete, amounted to 1,163,911 tons. (Board of Trade) In 1936, when it was most emphatically not obsolete, imports were 1,404,069 tons, (Whitaker, 1938) only 240,158 tons more, while in the summer of this war year of 1942, when imports must have been very much less, there were nearly 700 outbreaks of foot-and-mouth. (Since this was written certain information has been given to me, but which I am, unfortunately, not permitted to publish, which lends considerable support to Col. Pollitt's view that outbreaks of foot and mouth disease are due, in the first instance, to imports of uncooked meat. But even if this should be proved beyond doubt it still would not suffice to explain why farms in the middle of an infected area escape infection, while others with less direct contact succumb. Sound feeding will not of course remove *sources* of infection, but may, and probably does, give protection against anything less than mass doses of infection. Further evidence on this point is given on p. 69 and in Chapter VI.) When the prevalence of this disease is considered in conjunction with the increase in most other diseases, it is impossible to avoid the conclusion that our livestock is less robust than it used to be.

Disease in crops shows a similar upward grade. Potato diseases of various kinds, 'Take All' in wheat, blight, white fly and other parasites, and innumerable fungus and virus diseases are increasingly rife.

This close parallel in the decline of health in crops, livestock, and man is very significant, and evidence will presently be given indicating that the cause in all three is the same-faulty nutrition.

The food of our crops and domestic animals has undergone as marked a change during the last hundred years as that of man, and the change has been of a similar order.

'We are so made as to derive our sustenance from what was alive so recently that, somatically, it is still living' writes Dr. Picton.

It seems that it is not only desirable for our own food, whether animal or vegetable, to be as fresh as possible, but for those foods themselves also to be nurtured on a living diet. Until the war forced us to look once more to our own soil for the sustenance of our farm animals, this all-important element of 'freshness' had to a large extent been eliminated from the feeding of our livestock by the introduction of crushed seed cakes, and other imported processed foods. And the crops which we grow, whether for direct human consumption or as food for our livestock, are likewise being fed on substitutes for their natural diet of *living* organic matter. This change has resulted in our soil being seriously denuded of its humus content, with a consequent loss of fertility.

History suggests that a decline in soil fertilty is always accompanied by a corresponding decline in the vigour of the people who dwell upon it. To those who doubt this, I recommend a study of the fall of the first Roman Empire. The point was stressed quite recently in a broadcast by the Minister of Agriculture who affirmed that the basis of a strong nation lay in the fertility of its soil. The necessity to-day is to re-define the word fertility. I would remind you of a sentence in the Survey of Soil Erosion, quoted in the first chapter, that 'Increase of production must not be confused with increase of fertility. Increased production for human use can be, and usually is, secured by cashing in on existing fertility and using it up with the disatrous effects described.'

This is what has been happening throughout the world, but in this country the process did not really begin in a way that was serious until about 100 years ago, when chemical fertilizers were introduced. Before that time soil fertility was maintained by a combination of suitable crop rotations, bare fallows, and the application to the land of various forms of organic matter, principally farm-yard manure. In 1840 the famous German chemist, Liebig, published an essay, 'Chemistry in its application to Agriculture and Physiology', which has profoundly affected Western civilization. In this he propounded his theory of mineral plant foods. Roughly this rather naive theory is that everything required by a living plant is to be found in the mineral salts present in the ash of such a plant after all organic matter has been destroyed.

It seems a curious thing that this theory should have gained such ground as to overthrow all the experience and practice of the ages. This can only have come about through the confusion of thought with regard to fertility mentioned above. Man's understanding was blinded by the increase in production which the application of this theory at first brought about. Only the true peasant, the man who, despite all modern agricultural science, still has a truer understanding of the soil than any theorist, was not taken in. He shook his head and foretold the evils which were to come. Once more his views are well expressed in Adrian Bell's *Men of the Fields:*

'He had further ideas about food. "If people ate more of what's grown with muck, there'd not be half the illness about. People say that what's grown with artificial manure does you as much good as what's grown with muck. But I know that's wrong. What's grown with chemicals may look all right, but it ain't got the stay in it."'

But the age of science had dawned. Intuitive judgements were 'unscientific' and 'old-fashioned.' Liebig's theory could be 'proved'. Ocular demonstration was what counted. A given quantity of these new fertilizers produced the promised increase in yield. The methods of our forefathers were clearly out of date. 'There is a prevailing popular tendency to seek to replace "intuitive" methods, wherever they may be found, by "scientific" procedures. In this attempt we sometimes find that anything which can be dubbed "intuitive" is treated as though it were simply baseless speculation, whereas mere planned communicable routine often glories in the name of "science".' (R. C. Oldfield, *The Psychology of the Interview,* Methuen, 1941.) This tendency may have helped to establish the new soil science, in any case it was steadily gaining ground when it received a greatly quickened impetus after World War No. 1, through the necessity which faced those manufacturers of explosives, whose factories were equipped for the fixation of atmospheric nitrogen, to find other markets for their products. This resulted in the manufacture and use (assisted by a vast advertising campaign) of huge quantities of sulphate of ammonia and other synthetic fertilizers.

For some time, while the original supply of humus in the soil lasted, all seemed to go well, and in the difficult days of cut-throat competition that intervened between the two wars, when quantity rather than quality became the standard of efficiency, cultivators generally formed the habit of basing their manurial programmes on the cheapest forms of nitrogen, phosphates, and potash on the market.

All this time the 'man of the fields' remained unconvinced. 'Wait'; he said, with that patience only close contact with the soil can give, and now the indications are mounting that the day of his vindication is at hand, for there are signs that yields are declining, and that increasing quantities of fertilizers are required to produce a given return. But this is not all; quality is declining even quicker than yields. Fertility, as will presently be shown, depends on humus. The accelerated growth induced by chemical fertilizers has the effect among others, of speeding up the rate at which humus is exhausted. As this depletion of humus proceeded, troubles began. Parasites and diseases appeared in the crops, and epidemics became rife among our livestock, so that poison sprays and sera had to be introduced to control these conditions.

A very clear example of this is to be found in the case of some of the Lincolnshire potato lands.

The silt land area south of the Wash, now famous as the chief potato growing district in England, was, until a hundred years ago, equally famous for its pasture. This was so fertile that it was capable of producing prime fat bullocks without the assistance of any additional corn or cake. When these pastures were first ploughed up they produced abundant crops of healthy potatoes of good-keeping quality without the aid of fertilizers or poison sprays. Potato growing became so profitable that whole tracts of fertile grass land were turned over to the production of arable cash crops, with the result that farming became thoroughly unbalanced. Gradually chemical fertilizers became necessary to maintain yields, then diseases made their appearance, and spraying with copper salts had to be introduced to control blight. To-day it often happens that all the potato tops have to be destroyed with sulphuric acid before they are mature, in order to 'preserve' the tubers underneath. Lately a new trouble, eel worm, has become alarmingly prevalent. This, too, the experts are attempting to check by chemical means. The fallacy of this method when applied to eel worms will be shown in Chapter VI.

In recent years some Lincolnshire farmers have abandoned the use of fertilizers in favour of organic composts, with the result that health has been restored to the crops and the use of poison sprays is becoming unnecessary. I do not intend to suggest by this that all so-called artificial fertilizers are necessarily harmful in themselves, but as will be shown in the next chapter, other standards than those of chemical composition alone, are needed with which to assess their value. In any case, harmful, harmless, or beneficent, their use without adequate supplies of organic matter can never serve to replace the top soil which is mechanically removed from the land by the lifting of root crops. Such crops not only take from the soil the nutrients required to grow them, but large quantities of actual soil are carted bodily from the field in the process of harvesting. If this is not replaced by organic matter, the soil loses its 'life' and with it the humic cement which holds it together. It then becomes subject to erosion by wind or rain.

'The illusion that fertility can always be restored by applying some of the huge amounts of artificial fertilizers now available has been shattered by the recognition that fertility is not merely a matter of plant-food supply (for even exhausted soils usually contain ample reserves of plant food), but is also closely connected with soil stability. An exhausted soil is an unstable soil; Nature has no further use for it and removes it bodily. . . .

'The earlier stage of erosion is loss of fertility. Whatever the cause of the loss, the result is invariably a corresponding loss in soil stability; the soil is deprived not only of its productive power, but also of its capacity for remaining in place. Fertility is a term that should be applied to the soil and vegetation together, for the soil derives its capacity for producing life from the vegetation, as much as plants derive their capacity for growth from the soil. Apart from the indispensable plant-food elements and humus returned to the soil by the dead vegetation, the living vegetation protects the soil in many subtle ways from the erosive effect of wind and rain. . . . The capacity to absorb and retain water is a very characteristic property of mature, fertile soil. It is scarcely, if at all, developed in bare weathered rock formations (except heavy clays) that have never carried vegetation, and contain no humus. Normally the water-holding capacity of soil is confined mainly to a few inches on the surface where fresh humus, formed from decaying plant and animal remains, accumulates. Sheet erosion, by removing the most absorbent layers, not only greatly increases the amount of run off water which is the principal eroding agent, but equally decreases the value and usefulness of the rainfall. . . .

'The processes of wind erosion are less complex than those of water erosion. The predisposing conditions for wind erosion are (1) an absence of protective covering for the soil and a low fertility level, causing the soil to pulverize; (2) a dry period, as wet soil does not blow appreciably; and (3) a broad, flat or slightly undulating region across which wind and soil can move unhindered. Nature has arranged that where water cannot punish man for his ignorance and misdeeds, the wind can. When a large open area has been consistently mismanaged and its fertility reduced below the safety point, wind erosion can produce chaos within a few days.' (Jacks and Whyte, *The Rape of the Earth,* Faber and Faber, 1939.)

This was very noticeable in 1942 on the sugar-beet lands of Lincoln, Norfolk and Suffolk. This crop is nearly always grown with large quantities of fertilizers, and in many areas of these three counties, the conditions for wind erosion have been produced. During the period of high winds which occurred in May of that year, very many acres of land in these three counties under sugar-beet and carrots had their top soil blown clean away, carrying the crop with it. Some farmers had to sow as many as three times.

The appearance, in a crop, of parasites and disease is often the first symptom of that loss of fertility which, if ignored, is liable to lead to lack of soil stability. Such visitations therefore should be regarded less as an enemy to be attacked direct, than as a danger signal, warning the cultivator, while there is still time to repair the damage, that a serious misuse of the land is taking place.

'The policy of protecting crops from pests by means of sprays, powders, and so forth is unscientific and unsound, for even when successful, such procedure merely preserves the unfit and obscures the real problem--how to grow healthy crops.' (Howard, Speech at Crewe, 22nd March 1939. Reprinted *New English Weekly,* 6th April 1939.)

We shall see that the need for such protection seldom arises in those areas of cultivation where the tradition of peasant farming has never been broken, for the keystone of that tradition is the return of all wastes to the land. In almost every other type of farming, the soil has, during the last 100 years, been losing its organic matter faster than it is being replaced. This is due, not only to the excessive quantity of chemical fertilizers now in use, although this has accelerated the process, but also to the shortage of available organic matter which modern standards of civilized society have brought about, the three main factors being, the introduction of the petrol engine, the movement of the rural population into large urban areas (which the industrial revolution induced) and, perhaps most serious of all, modern sanitation.

When horse traction gave way to the internal combustion engine the land was robbed of millions of tons of horse manure previously produced in town as well as country, and when water-borne sewage was introduced into our cities, the capital of the soil--its fertility--which is removed from it year by year in the form of crops and livestock, no longer found its way back to the land in the form of the waste products of the community, but was poured into the sea or otherwise destroyed.

'On the basis of the data of Wolff, Kneller and Carpenter or of Hall, the people of the United States and of Europe are pouring into the sea, lakes and rivers, and into the underground waters, from 5,794,300 to 12,000,000 pounds of nitrogen, 1,881,900 to 4,151,000 pounds of potassium and 777,200 to 3,057,600 pounds of phosphorus per million of the adult population annually, and this waste we esteem one of the achievements of our civilization.' (G. T. Wrench, M.D., *The Wheel of Health.*)

King, in his classic, *Farmers of Forty Centuries,* writes: 'Man is the most extravagant accelerator of waste the world has ever endured. His withering blight has fallen upon every living thing within his reach, himself not excepted: and his besom of destruction has swept into the seas soil fertility, which only centuries of life could accumulate-fertility which is the substratum of all that is living.'

He points out that the Mongolian races with a population approaching 500 million, occupying an area 'little more than half of the United States, tilling less than 800,000 square miles of land and much of this during twenty, thirty or perhaps forty centuries, unable to avail themselves of mineral fertilizers, could not tolerate such waste and survive.' (Jonathan Cape, 1933, quoted Wrench.)

Nor shall we be able to survive indefinitely if we do not mend our ways.

The consequence of this process of denuding the soil of its fertility is only just beginning to be realized in Western countries. McCarrison has stated: 'These (certain natural foodstuffs), when properly combined in the diet, supply all the food essentials, known and unknown, discovered and undiscovered, needed for normal nutrition, provided they are produced on soil which is not impoverished, for if they be proceeds of impoverished soil, their quality will be poor and the health of those who eat them, man and his domestic animals, will suffer accordingly.' (Quoted in References to Medical Testament.)

Thus it will be seen that we cannot safely separate human health from the health of farm produce whether animal or vegetable. All have their origin in a fertile soil. Under field conditions a fertile soil is a live soil, and maintenance of life in such soil depends on humus.

This proposition is nowadays generally accepted in theory, but it is little understood in practice. Much of the existing confusion has arisen through a too frequent misuse of the word 'humus'. The term 'giving the land humus' is too often taken as a synonym for treating it with any form of organic matter, such as ploughing in green crops or grass, or applying farmyard manure. But all these substances are merely some of the raw materials from which humus can be made. They cannot become humus until they have been metabolised by soil organisms. It is essential that this fact should never be lost sight of.

Humus is a product of decomposition of plant and animal residues, through the agency of micro-organisms. It has been simply yet accurately defined as the product of living matter and the source of it. 'The chemical composition of humus is determined by the nature of the residues from which it is formed, by the conditions of its decomposition, and by the extent to which it is decomposed. Chemically, humus consists of numerous organic complexes, the major group of which consists of lignins and lignin derivatives, and of proteins; a minor group contains carbohydrates, fats, organic acids, alcohols and other carbon compounds. The formation and mutual inter-relations of these two groups of substances hold the key to the facts explaining the chemistry of humus.' (Waksman, *Humus.* (Baillière, Tindall and Cox, 1937.)

Under natural conditions such as obtain in virgin forest or prairie, a constant supply of raw material is provided by the native flora and fauna which live and die, so to speak, in situ. Their residues and remains are continually converted by the soil organisms into humus from which fresh life can spring. A perfect balance between growth and decay is established, and the fertility of the soil is permanently maintained.

In ordinary farm cultivation we have a very different picture. Here, the vegetable and animal life raised from the soil is continually, and more or less permanently, removed from the site of its origin. If this process is to continue, fertility can only be maintained in one of two ways; either by supplying large quantities of organic raw materials from which humus can subsequently be manufactured in the soil itself, or else by deliberately manufacturing humus *outside* the soil, and applying it to the land as a finished product.

Ploughing in green crops and applying farmyard manure are methods of accomplishing the first of these alternatives, but they do not of themselves supply humus. The higher the yields required of a crop, the more necessary does it become to convert the available raw materials into humus before they are applied to the soil. For natural humus formation in soil is a slow process, and heavy cropping tends to exhaust the supplies faster than they can be replenished; moreover, raw organic matter, which is mainly cellulose, cannot become fully available to plants until it has become humus, and the organisms responsible for the conversion, require, for the process of manufacture, many of the elements also needed by plants.

'Humus is a manufactured product with a carbon: nitrogen ratio of about 10 to 1, prepared from vegetable and animal wastes with a carbon: nitrogen ratio of about 33 to 1. The conversion, which is carried out by fungi and bacteria, is naturally accompanied by the evolution of large volumes of carbon dioxide and requires a corresponding amount of atmospheric oxygen. Besides air, the organisms concerned in the manufacture also need water, a base to neutralize excessive acidity, and sufficient minerals, particularly combined nitrogen. Their demands are almost identical with those of the roots of plants. It follows therefore that any attempt to prepare humus in the soil itself is almost certain to interfere with the crop. Hence the injurious effects on growth which almost invariably follow the addition of straw, and very frequently, of green manure to the soil. In such cases, the decomposition of these materials impoverishes the soil solution, contaminates the soil atmosphere, and often depletes the soil moisture. The result is that the soil is overworked and a poor crop is obtained. This overwork can be avoided by taking care to prepare humus outside the field rather than in the soil itself, and to restrict green manuring to localities where all these factors can be relied upon to yield a satisfactory result. (As for instance, in biologically active soil where the ploughing in is done in July or August between the spring and autumn nitrogen cycles.) The Chinese were the first to grasp and act upon the master idea that the growth of a crop involves two separate processes: (1) the preparation of humus from vegetable, animal and human wastes, which must be done outside the field, and (2) the growing of the crop.' (Howard, *Manufacture of Humus by the Indore Process*. Royal Society of Arts, 1935).

There are districts in China where the Chinese peasant, by adhering to this principle, has intensively and continuously cropped his soil without loss of fertility for forty centuries.

By 'humus manufacture' is meant deliberately speeding up the normal rate of cellulose decomposition. The process by which this is achieved is called 'composting'.

Composting is as old as agriculture. There is some evidence that many of the ancient civilizations, when in their prime, based their cultivation on systems of composting and irrigation, but whereas the primitive methods were, presumably, devised empirically, in recent years the knowledge contributed by biology, mycology and bio-chemistry has enabled a much more scientific approach to be made to the whole question of humus manufacture, and very exact and greatly improved methods of composting have resulted. While different methods vary as to certain factors and details of procedure, one fundamental principle underlies all successful compost making. Decomposition must take place by fermentation, and not by putrefaction. This involves careful control of the air supply, moisture content, and temperature developed in the compost heaps. Where these points are not properly attended to, the process has no right to be called composting, and the resultant product is not humus. It would be tedious in a book of this kind to describe in detail the different methods of composting in current use. To those who would like to make a comparative study of them I recommend a booklet by F. H. Billington, called *Compost,* (Faber and Faber, 1942) which contains a summary of them and also an excellent bibliography showing where further information can be obtained. Here I shall confine myself to a description of one method only; that devised by Sir Albert Howard in the course of his research work in India, and now generally known as 'The Indore Process of Humus Manufacture'.

My reasons for choosing this method are, firstly, that I have practical experience both in its manufacture and in the excellent results following its use, and secondly because, of all the purely organic methods that I know of, Howard's seems to me to be at once the most adaptable to all systems of farming or gardening, and the most foolproof. This is an important point, for no method is likely to be widely adopted by practical cultivators, unless it is capable of being reduced to a formula, which, while precise, must also be simple. Howard points out that:

'When the Indore process in its final form was devised between the years 1925 and 1930, the scientific approach to the utilization of crude organic matter left much to be desired. The chief organic residues--farmyard manure, green manure, vegetable residues, municipal wastes, sewage sludge, and crude sewage, were being studied separately, and not as parts of a single subject. Much of the scientific work had been done, but the various fragments were lying around in the literature very much like the materials in a builder's yard, before the building itself is erected. On the practical side difficulties were being experienced. The results of green manuring were erratic; most of the methods of managing agricultural residues resulted in the loss of valuable nitrogen; some were elaborate, and some expensive; there was no idea of examining the experience of old cultivation systems like the Chinese, the successful continuance of which over several thousand years is proof of efficiency, and illuminating them by the light of modern science.

'It is claimed that the Indore process has solved these difficulties. What was needed was the welding together of the separate fragments into a single well-ordered method, elastic enough to be introduced into any system of agriculture. In the course of its working out, the Indore process has been founded on correct bio-chemical principles, and is not far removed from Chinese or other more primitive practices evolved empirically in many parts of the world.' (Howard, *Manufacture of Humus by the Indore Process*. Royal Society of Arts, 1935).

The manufacturing process itself takes place in compost heaps or pits. The technique is simple, but must be followed with precision.

The materials needed are animal and mixed plant wastes, a base for reducing acidity, air, and water.

The plant wastes may include all vegetable and crop residues to be found on the farm or in the garden, such as weeds, leaves, grass, tree and bush prunings, hedge and bank trimmings, straw and chaff, and dust-bin refuse.

If the proportion of fresh green material is likely to exceed 30 per cent, any excess must be withered before composting begins, otherwise there is a danger that silage rather than humus will result from the operation.. This rule does not apply to small garden heaps. These can safely be made exclusively of fresh green material, provided very soft fine wastes like lawn mowings are mixed with the coarser rubbish. It is only in the large farm heaps that over-consolidation is liable to occur. The different categories of plant wastes should be well mixed, and where these are very long it is helpful to break or cut them into shorter lengths.

The greater the variety of materials that go to make up a compost heap the better will be the quality of the end product, nevertheless very good compost can be made with FYM and straw only. (See Chapter VIII.)

Any available animal manure may be used, but it is important that the urine of the animal be carefully preserved because this contains the drainage of every cell and gland in the animal body and is therefore rich in accessory growth substances.

As a base, earth, wood ash, chalk, sea sand, or a mixture of some of these substances should be used. Quick lime (CaO) should be avoided as its action is too fierce in the heap. Slaked lime ($Ca(OH)_2$) is better, but some form of calcium carbonate ($CaCO_3$) is greatly to be preferred. This will neutralize excessive acidity and at the same time provide suitable conditions for the fixation of nitrogen. Whether heaps or pits are employed will depend on local conditions, of which the site chosen and the rainfall are among the most important. If the site is sheltered, and there is any danger of waterlogging, heaps are best; but they must be protected from too much exposure to cold drying winds. Pits have the advantage of retaining the heat better and of requiring less water. In this country heaps are usually the most satisfactory, and the method of assembling is as follows:

The heap should be made 10 feet wide, up to any total length required, but the length should be made in 5-foot sections, each section being completed before the next section is begun.

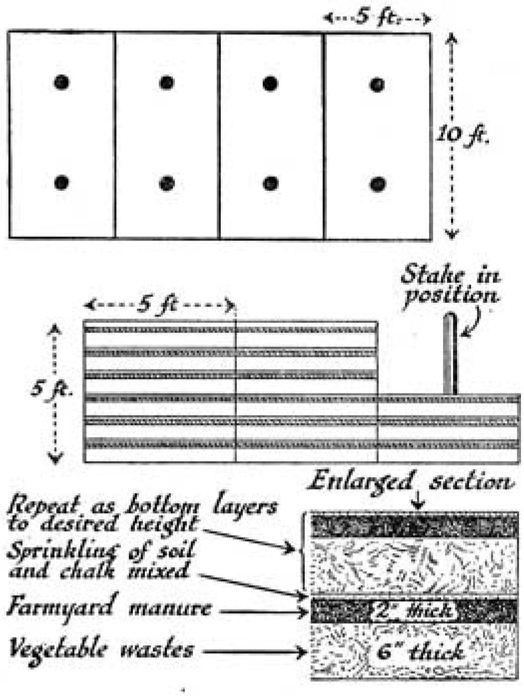


FIGURE 1

Each section should be built up to a height of between 4 and 5 feet. That is to say, the ground plan of each section will be 10 feet x 5 feet, and the elevation not less than 4 nor more than 5 feet. The mass should sink, after settling, to a height of about 3 feet. Failure to do so is an indication that insufficient air has made its way into the heap or that the heap is too dry, in either of these cases humus manufacture will be delayed.

As each section is completed, two vertical air vents should be made with a crowbar or similar implement, which must be worked sideways to leave a hole 4 inches in diameter. In practice the easiest way to do this is to place two six-foot stakes in position before the section is begun, and then to build up the section round them. They can be worked backwards and forwards in the course of construction, and easily withdrawn when the section is completed.

The sections are built up in layers. First, a layer of mixed plant wastes, 6 inches thick, then a layer of farmyard (or other animal) manure, 2 inches thick, then a thin sprinkling of earth, not more than two or three shovelfuls, containing some wood ash, or chalk, or whatever base is available. This sandwich process is repeated until the requisite height is reached, each section being finished off with a liberal covering of earth an inch or more in thickness. (See Fig. 1.) Where heavy material like ordinary FYM forms the principal ingredient of the 'animal' layer, the sections should be made without standing on them or over consolidation will take place with a consequent interference with the air supply.

In theory the ratio of plant and animal wastes should be such as to supply 1 lb. of nitrogen to every 1001b. of dry vegetable matter. In practice, it has been found that it is sufficiently accurate if the ratio of mixed plant wastes to farmyard manure is 3 to 1 by volume.

If the material is dry, the layers must be watered as they are made.

After three weeks the heap should be turned from one end by slicing it vertically like bread, so that the different layers become thoroughly mixed, but care must be taken to see that the outside dry material is put in the centre.

As each section of the turned heap is remade (but this time only three feet high), the air vents should also be remade, and the layers watered again if necessary. At no time should the heap be dry, but it should not be sodden. Too much moisture causes the heap to pack, and interferes with the air supply. The amount of moisture should resemble as far as possible that of a squeezed-out sponge. At the end of a further three weeks, the heap should be turned again in the same way, but no further vertical air vents are required.

Soon after the heap is first made an intense fermentation sets in, accompanied by a rapid rise in temperature to about 160.0° F., which continues for a long time, with a gradual downward gradient to about 90.0° F. This range fits in well with the optimum temperature required by the organisms which break down cellulose. The aerobic thermophilic bacteria thrive best between 148.0° F. and 180.0° F., and the fungi between 97.0° F. and 130.0° F.

When the first turn is made the whole mass will be found to be covered with greyish-white mycelium: About seven to ten days after this first turn, the material begins to crumble and darken in colour. Bacteria from now on take the leading share in the manufacturing process, which at this stage becomes anaerobic.

Six weeks after the second turn, that is to say about three months from the beginning, the carbon nitrogen ratio of 33 to 1 in the original mixture will have fallen to about 10 to 1. The whole mass has become humus, resembling in colour and texture old leaf mould. It is now ready for the land.

At first sight this procedure may appear complicated, but I can state explicitly from personal experience that in practice it is quite simple.(A still further simplified method is described in a few paragraphs. For the small garden cultivator see Technical Reference No. 4.) I must, however, repeat that for optimum results it is essential that the routine be closely followed. The reason for this is that the value of a compost to plant life depends not so much upon its chemical composition, as upon its biological reaction, particularly in relation to the activities of soil fungi. Proof of this will be given in the next chapter. If the proper temperature is not achieved at the right time, it means that a less desirable set of organisms are at work.

'The vigour of fungal action at the earlier stages of the composting process is evident from the abundance of mycelium present and the profusion of sporophores intermittently produced on the surface of the heaps. A relatively early stage of decomposition is marked by great activity of thermophilic organisms, indicated by the development of temperatures ranging from 50° to 70° C. It is believed that the chemical changes brought about during this stage of composting are of critical importance in determining the value of the final product.' (Professor Neilson-Jones, 'Biological Aspects of Soil Fertility, *Journal of Agricultural Science,* Vol. 31, part 4, Cambridge Press, 1941. Republished in *Problems in Tree Nutrition,* by M. C. Rayner and W. Neilson-Jones, Faber and Faber, 1944.)

A wet airless mass of rotting vegetation is decomposed not through the activities of these aerobic organisms but through the agency of putrefactive bacteria.

Some specialists never think of making compost without the aid of a thermometer, but there are plenty of signs which the compost maker very quickly learns to recognize, which tell him if the process is developing correctly.

Among the good signs are: (1) copious 'steaming' from the ventilation holes; (2) the spontaneous appearance of sporophores (In cold weather these will be found just *under* the surface of the heaps.) on the heaps referred to above (see Plate 1); (3) an even distribution of mycelium, appearing like greyish-white mildew throughout the heap at the first turn; (4) the invasion of the heap by earthworms, which should be evident at, or soon after, the second turn; (5) a sweet earthy smell.

PLATE I. Recently made compost heaps showing spontaneous appeareance of sporophores (toadstools)

Signs of faulty manufacture are: (l) absence of the good signs listed above; (2) a 'bad' smell, or else a smell of ammonia; this last means that loss of nitrogen is taking place, and is a sign of faulty aeration-it usually indicates that the heap is too wet or too tightly packed; (3) flies frequenting the heaps or breeding on them; (4) failure of the heap to settle; this usually means that it is too dry.

All that is required to avoid mistakes is attention to detail and a little experience as to how to vary these details slightly to meet different weather conditions.

'Over-acidity, faulty aeration, too much moisture, or an unsuitable site-any of these may present a passing problem in this country (owing to cold and wind). Such problems must be tackled in the light of the special circumstances giving rise to them. In no case yet have they proved insoluble.' (Howard, 'Manufacture of Humus by Indore Process'.)

I can assure you that composting is a fascinating game that grows on you.

When you make compost for the first time according to this recipe, it seems like a miracle that no matter what activator is used-pig muck, blood, night soil, or sewage sludge--the final product is inoffensive to crumble with the bare fingers, and has the pleasant earthy smell of old leaf mould.

It is not always feasible to collect all vegetable wastes of a farm for composting in heaps. Some of these wastes will be crop residues still growing in the field, or else grass and clover leys to be ploughed up, or even crops specially grown for ploughing in as green manure. In these cases the operation known as *sheet composting* can be adopted. There are two methods of accomplishing this. The first is to dress such crops with farmyard manure during the summer while they are still growing (in the case of grass the best time is directly the first cut of hay is off), next allow the crop to grow up through the manure to a height of eight inches to one foot, then plough-not too deeply--while there is still enough warmth in the soil for decomposition to take place. September is the latest month in which this can be done. This method is very successful, complete decomposition taking place in good time for an autumn seeding.

The second method is essentially the same, but the manure is deposited on the crop by close grazing with livestock, instead of being made in the yards and carted on. When this method is used the stock must be removed in time to allow the crop to grow to the requisite height before the August or September ploughing.

'One of the earliest and most effective examples of this process was originally devised by Mr. Hosier on the poor chalk pastures of Wiltshire. Following the introduction of the bail system, (Under this system the cows are kept in out-door folds, the movable milking plant known as the bail following them round the fields.) the undecayed organic matter in the original turf was rapidly converted into humus by means of the urine and dung of the cow. The herbage improved until about the fifth year when no further progress was made. The turf was then ploughed up and converted into humus for the benefit of two or three straw crops, followed again by a temporary ley.' (Howard, 'The Manufacture of Humus by the Indore Process', *Journal of the Ministry of Agriculture,* 1938).

It is often asked whether the time and trouble involved in composting can be justified financially, so let us look at some of the advantages of the operation.

First and foremost must be placed the high degree of disease resistance in both crops and livestock that appears to follow liberal applications of well-made compost. Evidence on this point will be considered later. Second, the process enables all rubbish, wastes, and weeds of the farm to be utilized profitably. Third, the loss of nitrogen which usually occurs in the ordinary manure heap is avoided, as well as the bad smell and the formation of fly-breeding sites, and lastly, three times the bulk can be made from the same head of livestock, and there is evidence to show that the resultant product is superior. A large scale test, involving forty fields, was made on the late Sir Bernard Greenwell's estate of humus manufactured by the Indore process versus best quality farmyard manure, that is to say, well-rotted manure that was practically pure dung. Load for load the compost showed in every case better results. (*Journal of the Farmers' Club,* 1939).

In 1942 I carried out a somewhat similar test to determine the relative merits, ton for ton, of Indore compost and *fresh* farmyard manure. The crops chosen were potatoes and brussels sprouts, followed, in 1943, by oats and barley respectively. In the case of the potatoes, compost at 6 tons per acre produced substantially the same result as farmyard manure at 12 tons per acre. In the case of the sprouts, where the compost and farmyard manure were both applied at the rate of 7 tons per acre the crop was markedly better on the composted portions. In both cases the 1943 cereal crop was better where compost had been used, showing that the previous year's results were not merely due to plant food in the unrotted farmyard manure not being fully available to the first season's crop. A detailed description of this experiment is given in Chapter VIII. The results, which fully endorse Sir Bernard Greenwell's findings, have an important bearing on the economic aspect of composting, for they indicate that the output, in farmyard manure, of a given head of livestock is capable of maintaining the fertility of two or three times as much land when it is made into compost as when it is applied to the soil direct, since the proportion of farmyard manure to vegetable rubbish in compost is one-third by volume. This is an important point, especially in war-time when the livestock population is so much reduced. The objection to composting on the grounds of labour costs is a point which I shall discuss later. Many farms are now solving the problem through mechanization, but I may just observe at this point that, using the Indore method, two men can by hand manufacture 1,000 tons of finished compost per year, and that once land has been restored to fertility, an average of five tons per acre per year is sufficient to maintain fertility. This means that two men can make enough compost for 200 acres. This, translated into cost of man hours per acre, compares favourably with the amount many 200 acre farms now spend on artificial fertilizers and poison sprays. In war-time, however, the difficulty is likely to be less a question of the cost of labour, than of shortage of labour. Where, for this or other reasons, it is found impossible either to sheet compost, or to manufacture humus by composting in heaps, the next best method of handling farmyard manure is as follows: Use much more litter in the yards than is the usual custom, so that the right proportion of cellulose to dung is achieved at the outset. (As a rough and ready guide to the amount, always keep the yards looking clean, and never 'mucky'.) Make as much variety as possible in the littering, using in rotation all the different cereal and pulse straws that are available on the farm. Any portion of a root crop, hay, or silage fed to the cattle, and not eaten, also of course becomes incorporated in the bedding. The chalk and soil can be added from time to time, as well, or the whole yard spread with a layer of these materials immediately before it is cleaned out so that it gets automatically mixed during the process of carting. The addition of soil when composting is thereby rendered unnecessary except for a top covering as each section is completed. By this method all the ingredients are assembled together while still under the cattle. When the yards are cleaned out, cart the manure to the field where it is to be used if possible not less than three months before it is necessary to apply it. There make it into a 'muck hill', but build it up in sections exactly as if it was compost. That is to say use stakes for ventilation holes, and avoid standing on the sections. It is permissible to make the sections one foot bigger in all directions, than compost sections, i.e. 6 ft. x 12 ft. x 6 ft., but in this case it is advisable to make three ventilation holes. In three months, even without any turning, the material in the heap, though not fully decomposed, will be found to be short and friable, and will smell like compost and not like manure. It is half-way to compost, and while not so ideal as the latter, is greatly superior to ordinary farmyard manure. If time can be found to turn it, perfect compost results. One point more. Compost can be applied at any time of year and in any quantity. It should be used either as a top dressing, or ploughed or harrowed into the top few inches of soil, where the aerobic organisms live. It should never be buried deeper than 6 inches.

Some mention must now be made of Howard's research work in India in the course of which the Indore process was evolved. Just as McCarrison succeeded in preventing disease among his rats by diet alone, so did Howard succeed in the prevention of disease among his crops and livestock by treating the soil with manufactured humus. In fact a very significant parallel exists between the experimental work of these two men.

Although their investigations were carried out quite independently, one in the medical and the other in the agricultural field, these can now be seen to have been complementary, forming two parts of a connected whole.

Both McCarrison and Howard began their research work on nutrition from the conventional approach of pathology. Both came to see that in order to discover the secret of health it is necessary to study the healthy and not the diseased organism. Both had the good fortune to be provided at a critical moment in their careers with ample facilities for untrammelled research. McCarrison, when he was appointed Director of Nutrition Research in India and given his laboratory at Coonoor, and Howard when he was appointed Imperial Chemical Botanist to the Government of India at Pusa. Here, he tells us, he was for the first time provided with 'real facilities for work, land, money, and freedom to grow crops in my own way, and to observe among other things the reaction, to insect and fungus pests, of suitable varieties when properly grown. My real education as an investigator then began-six years after taking my degree and after obtaining all the paper qualifications then needed for research. My duties at the Pusa Research Institute, fortunately for me, had not been clearly defined and I escaped the fate of many of our agricultural investigators-a life devoted to a research organization already becoming obsolete. It was possible, therefore, to attempt to break new ground and to try out an idea which had occurred to me in the West Indies, namely, to see what happened when insect and fungus diseases were left alone and allowed to develop unchecked, and where indirect methods only, such as a combination of better varieties and improved methods of agriculture, were employed to prevent attack.'

He took up all the land that was still available at Pusa, some seventy-five acres, and spent his first five years in India ascertaining by practical experience the principles underlying health in crops. He found that his best teachers were the peasants of India themselves, and the insects and fungi which attack crops.

'By 1910,' he writes, 'I had learnt a great deal from my new instructors--how to grow healthy crops practically free from disease without any help from mycologists, entomologists, bacteriologists, agricultural chemists, statisticians, clearing-houses of information, artificial manures, spraying machines, insecticides, fungicides, germicides and all the expensive paraphernalia of the modern Experimental Station.'

In the course of the work which resulted in this very considerable achievement, Howard formed the opinion that the key to disease resistance was a fertile soil, and that soil fertility could not be brought about by the use of artificial fertilizers, but was absolutely dependent on adequate supplies of humus. His subsequent experiments convinced him that the best results are obtained when humus is scientifically manufactured outside the field, and that this humus is only fully effective if composed of both vegetable and animal waste products.

Before the Indore process was evolved, tests were made to see if the same results could be obtained without the compost containing any proportion of animal wastes; but the peculiar power of humus to give resistance to disease was markedly less when the animal element was omitted.

'Ill-advised attempts in Ceylon to make compost with vegetable wastes alone have resulted in failure for the investigator himself and hindrance and discouragement for the other planters who were tempted to follow his example. The actual growth following the application of compost made from vegetable wastes alone is definitely improved, bu no resistance to disease is established-indeed, a reverse effect has been observed.

'On the other hand, I have before me two reports from estates in Africa where animals have lately been included in the estate economy solely for the purpose of making up the necessary complement of animal wastes in the compost heaps, with extraordinarily impressive results. Large-scale experiments will soon provide incontrovertible evidence on this point; but it has been clear to me since the inception of the Indore process that animal wastes, even if (as in certain places in Great Britain) such substitutes as dried blood are resorted to in the absence of farm yard manure, are absolutely necessary.' (Howard, *Humus*. Revista del Instituto de defensa del Cape de Costa Rica, 1939).

An explanation for the failure which usually results from the omission of the animal element will be given in Chapter V.

Howard further reached the conclusion, as a result of his experiments, that crops have a natural power of resistance to infection, and that proper nutrition is all that is required to make this power operative. Here was a close parallel to the rats of Coonoor; but in comparing the work of McCarrison and Howard, a point of particular interest emerges. When McCarrison's rats reached an age comparable with the fifties in human life, those which had been fed on the sort of food common among English working people were found, you will remember, to suffer from the same degenerative diseases which are rife amongst our population, while complete freedom from such diseases was displayed by the rats fed on the food of Hunza or Sikh, but McCarrison did not, so far as I am aware, attempt to cure the sick rats by a return to the Sikh diet, nor does he appear to have tested the two groups for their comparative powers of resistance to *infective* diseases.

The results of Howard's work on the other hand suggest that crops and livestock raised on land made fertile by his methods of humus treatment attain a high measure of immunity from infective and parasitic, as well as from degenerative diseases. Further, it would appear that this treatment is curative *as well* as preventative. (See Chapter VI.)

In three centres in India, Howard was in control of extensive areas of land for a period of twenty-one years, and there he was able to carry out tests to prove his theories.

He claims to have found that the factor 'that matters most in soil management is a regular supply of freshly made humus, prepared from animal and vegetable wastes and that the maintenance of soil fertility is the basis of health'. (Howard, quoted from Medical

Testament.) He further claims that his crops grown on land so treated resisted all the pests which were rife in the district and that this resistance was passed on to the livestock when these were fed on crops so grown.

'I then took steps to have my own oxen and to ascertain from firsthand experience the reaction of well-chosen and well-fed animals to diseases like rinderpest, Johne's disease and so forth which are common in India. After a short time my animals duly came into contact with other oxen suffering, among other things, from foot-and-mouth disease.

'I have myself seen my oxen rubbing noses with foot-and-mouth cases. Nothing happened. The healthy, well-fed animal reacted towards this disease exactly as improved and properly cultivated crops did to insects and fungi-no infection occurred.

'These preliminary results suggested that the birthright of every crop and of every animal is health and that the correct method of dealing with disease is not to destroy the parasite but to make use of it for keeping agricultural practice up to the mark-in other words to regard the diseases of crops and livestock as Nature's Professors of Agriculture. These ideas were put to the test during the next twenty-one years at three centres in India, at all of which I had to manage large areas of land, and look after numerous oxen: Pusa (1910-24) ; Quetta (summers of 1910-18); Indore (1924-31). Everything possible was done to grow crops properly; everything possible was done for the livestock as regards food, hygiene and general management. The result was freedom from disease.' (Howard, quoted from Medical Testament.)

These remarkable results are by no means isolated.

The Indore process has since been put to the test in other parts of India, and also in many widely separated places throughout the world, including this country. Its adoption has been attended by remarkable, and sometimes even spectacular, results.

Representative examples of these results will be given in a later chapter, but first, in order that you may be in a position to form an unbiased judgement on the value of the evidence that can be deduced from them, it is necessary that the true nature of compost action should be made clear. Its behaviour differs widely from that of an ordinary manure, and it is important that this fact should be grasped, and the reasons for it understood.

CHAPTER IV
DIRECT EVIDENCE *

'The soul dares not believe its own marvellous guesses and instincts
unless it can fall back on definite dogma for confirmation.'
Coventry Patmore

(*This chapter, and the one following it, are very important to the argument of the book, but it is not essential that they should be read by the non-scientifically minded, or by those who are only interested in the conclusions to be drawn from them. Any reader, therefore, who finds them stiff, will lose little by reading the rest of the book first.)

I have stated that Howard and others claim to have proved by practical field tests extending over a number of years, that humus treatment confers on plants a power of disease resistance amounting in some cases almost to immunity, and that a like result is not, and cannot be, obtained by the use of artificial fertilizers. These views, however, are by no means universally accepted; it is therefore necessary to examine in some detail the scientific evidence in support of them.

As this assumes the probability that the soil micro-flora plays a direct and important part in the nutrition of the higher plants, I must first present the evidence on which this assumption is based.

This is an extremely complex subject, and a wide diversity of views exist concerning it, many of them still controversial. That soil fungi are capable of utilizing complex organic substances not directly available to higher plants, and of breaking these down into simpler forms, is an established fact. That many of these fungi also excrete substances that appear to act as a stimulant to growth also seems clear from the evidence. But the now very considerable and growing body of research work on mycorrhizal association seems to suggest that very many plant species and families benefit from the presence of specific soil fungi in a particular and intimate way.

The history of this research goes back nearly 100 years. Thread-like structures within the root cells of certain vascular plants were noted as early as 1829, and by 1847 were identified as being fungus mycelium. Frank described the 'dual structure formed by the tree root with its associated mycelium' under the name of *Mycorrhizal* and the name has stuck. (From Myco=fungal, and Rhiza=root. Should strictly only be used to denote a true fungus root, but is often loosely used to describe all mycorrhizal infection.)

'The outstanding results of Frank's preliminary investigations, were, firstly, the recognition of root infection as a widespread phenomenon in trees, and the bestowal upon it of a distinctive name marking its existence as a morphological entity; and, secondly, the rejection of the accepted view of parasitic invasion of these roots, whether by truffles or other soil fungi, and the substitution of his theory of a symbiotic relationship beneficial to the trees. The far-reaching character of this hypothesis was a direct incentive towards the collection and interpretation of new facts bearing on the subject.' (M. C. Rayner, D.Sc., *Mycorrhiza.* Cambridge Press.)

This collection and interpretation has gone on ever since. It is a fascinating story, and has been fascinatcngly told by Dr. M. C. Rayner in her monograph on the subject. (M. C. Rayner, D.Sc., *Mycorrhiza.* Cambridge Press.)

Since ignorance concerning this aspect of plant nutrition is very widespread, it may be helpful to give a very brief description of the mycorrhizal habit.

Mycorrhizas are usually classified, according to their structure, into two main groups, called ectotrophic and endotrophic, though these structural types are not nowadays considered to be sharply marked off one from the other.

The mycorrhizas of many trees and shrubs belong to the former group. These can easily be recognized by their outward appearance as distinct from ordinary rootlets. They form the short root system of such trees as pines and spruces, and members of the oak and beech family. A sheath of mycelium is formed over the tip of the young rootlets, and the internal fungus infection is mainly *inter*cellular.

Members of the second group resemble ordinary roots to the inexperienced observer, though it is often possible to identify them by irregularity in diameter and differences in opacity. The fungus infection of this group is mainly *intra*cellular, the mycelium within the cell walls eventually undergoing complete digestion by the plant cell. This process is plainly visible under a microscope (see Plate II). It is to this group that the mycorrhizas of the majority of crop plants belong.

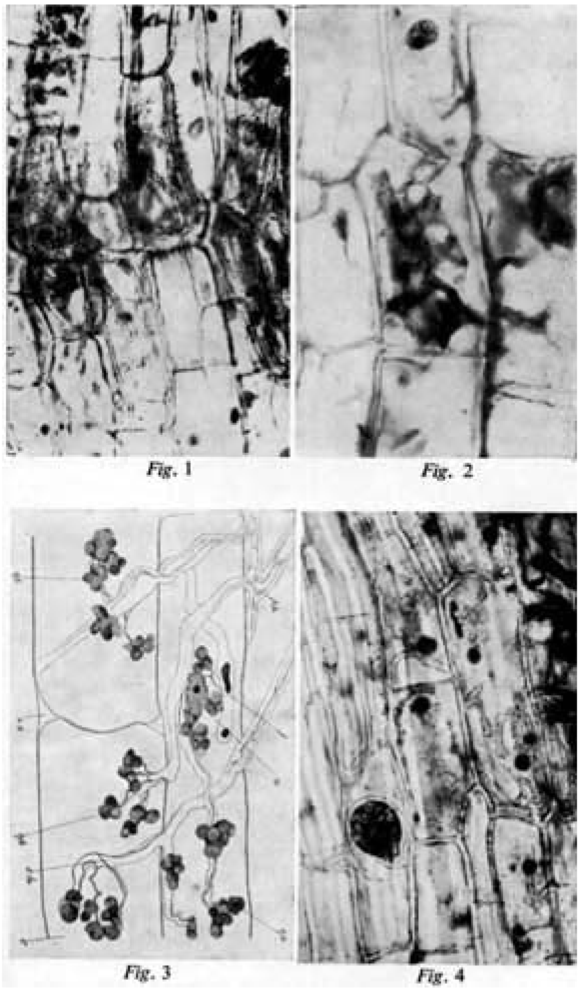


PLATE II. *Fig.* 1. Longitudinal section through a mycorhizal root of Tea, showing coils of active hyphae within the cell, and passing from cell to cell. Magnified about 450 times. *Fig.* 2. Ditto, showing disorganized and digested hyphae within a cell. More highly magnified than *Fig.* 1. *Fig.* 3. Longitudinal section through micorrhizal root of grass (*Lolium Temulentum*) showing adanced stage of digestion of intra-cellular hyphae. *Fig.* 4. Longitudinal section through a micorrhizal root of Lawson's Cyprus showing coils of active hyphae within the cells. A vesicle formed by the infesting fungus is shown towards the left of the photograph. *Figs.* 1, 2 *and* 4, from original photomicrographs. *Fig.* 3 from an original drawing.

The function of mycorrhizal association has been, and to a certain extent still is, a matter of controversy. The views of the early investigators ranged from the theory that the association was an accidental parasitic attack injuring the roots, to that of a mutually beneficent symbiosis, playing an indispensable part in plant nutrition.

The effect of the most recent research is to discredit entirely the first view. A phenomenon can hardly be accidental that occurs 'in wild and cultivated plants; in those growing in tropical forests and within the Arctic Circle; in habitats so different as the high Alps and the salt marsh, affecting an immense number of species of diverse families and occurring regularly under the most varied conditions of climate and soil.' (Rayner, 'Mycorrhizal Association in Crop Plants', *Empire Cotton Growing Review.*) The list of known mycorrhiza-formers is being continually extended; at present it includes among tropical and sub-tropical crop plants, tea, coffee, sugar-cane, oil palm, coconut, cocoa, rubber, and tobacco; and among those grown in these islands and Europe, grasses including the cereals, potatoes, vine, hops, clovers, peas, beans and other leguminous crops, as well as many wild plants. Truly 'the habit challenges attention as a factor of significant potential importance to practical growers'. (Rayner, 'Mycorrhizal Association in Crop Plants', *Empire Cotton Growing Review.*)

The theory of parasitism is equally untenable. In some highly specialized groups such as some of the orchids and heaths, the mutualism is so clearly defined that in some cases normal seedling development depends, under natural conditions, on the presence of the fungus. (For example Ling or Scotch Heather (*Calluna Vulgaris*). See Rayner, *Mycorrhiza,* p. 96.) In others the host plant dies or suffers from completely arrested development without its fungus associate. See below. Also experiments with beech described in *Mycorrhiza,* p. 24.) In other less specialized varieties, it has been noted, among all those that have been closely studied under natural conditions, that the healthiest, most vigorous plants are those with the most active and widespread fungus infection, whereas in poorly developed and unhealthy plants, infection is weak and localized or even absent, so that to accept the theory of parasitism 'involves the paradoxical assumption that healthy growth is invariably accompanied by decreased resistance to parasitic attack, and by the production of an absorbtive system the major part of which is hampered by fungal interference'. (Rayner, *Forestry*, 1939.)

Since vigorous fungal activity in soil is dependent on adequate supplies of humus, it should now be clear that some knowledge of the part played in the life of the higher plants by soil microflora and fauna in general, and mycorrhizal association in particular, is an indispensable equipment of any would-be entrant into the arena of the Humus *v.* Chemical controversy, yet it is my experience that the majority, if not all, of the disinterested advocates of chemical fertilizers are totally ignorant of the subject, and that their ignorance is shared by many of their opponents in the humus camp.

This ignorance is perhaps excusable when it is remembered that even to-day few botanical text-books give an adequate or unbiased account of mycorrhizal association, (An exception is *Biology of Flowering Plants* by Skene.) and still fewer indicate the potential practical importance of this widespread habit among vascular plants.

Indeed the extent to which the whole subject has been ignored, even by accepted experts in soil science and plant physiology is difficult to understand. It is probably due to a variety of causes, of which the principal one is, I think, the over-emphasis on chemistry which, since Liebig, has been a feature of agricultural and horticultural research. This has resulted in soil chemists rather than soil biologists being placed in control of experimental stations. Secondly, soil biologists have tended to focus their attention on *specialized* groups of soil organisms such as, for example, nitrogen-fixing bacteria, and specific parasitic fungi. They have largely overlooked the general relationship of the soil micro-flora with *normal* plant growth.

This fragmentation, while understandable, nevertheless seems to me to be the curse of much modern research. Whatever we study, our tendency is to break it up into little bits, thereby destroying the whole, and then to study the effect or behaviour of the separate pieces as though they were independent, instead of--as in fact they are--interdependent.

The importance of the science of ecology in all fields of living matter has been increasingly realized in recent years, and it is recognized that the study of plant ecology is still in its infancy. Using the same analogy one might justly say that the study of soil ecology is in the pre-natal state. There are, however, signs that the birth pangs have begun, and the infant, when it arrives, promises to be a lusty one, destined perhaps to play a vital part in man's better understanding of how to live.

When this happens no research worker will have a greater claim to rank among the chief assistants at its birth than Dr. Rayner. Her recent work on mycorrhizal association has been mainly concerned with trees, and her investigations are quite separate from, and independent of, any of the aspects of soil fertility and health dealt with in this book. Their importance in connection with this subject rests mainly on the fact that an incidental result of her work has been greatly to elucidate the nature of compost action, and the effects of its application on the soil population.

The exact manner in which associated or other soil fungi benefit higher plants is a question on which experts still differ. I discuss some of the different theories in the next chapter. The accurate answer to the question is of immense scientific interest but from the practical point of view it is more important to establish the fact that the plant does benefit, and in a way that is vital, either directly from the presence of these fungi, or from soil conditions which also favour free fungal development, for obviously if such a fact were fully established in regard to crop plants the implications would be very far-reaching. Among other results would be a complete justification of Howard's conclusions, for, as already stated, fungi thrive in humus and cannot live in soil without it; moreover there are indications that soil fungi are inhibited by many chemical fertilizers. (See chapters V and VI.)

The difficulty of providing critical proof of the beneficent action of soil fungi on crop plants arises from the paucity of direct scientific evidence regarding the physiological role of endotrophic groups of mycorrhizal fungi in plant nutrition, from the scattered nature of the circumstantial evidence, and from the extreme complexity of the subject. This last may well be responsible for the different results sometimes obtained by different investigators concerning the relative merits of organic versus chemical soil treatments.

My difficulty, therefore, in adventuring into this sea of cross currents was to find a really secure anchorage from which to start. When, in the course of extensive reading on the subject, I obtained access to the reports of Dr. Rayner's recent work on trees at Wareham Forest, I decided, rightly or wrongly, that I had found such a starting point.

True, these investigations were concerned with the ectotrophic mycorrhizal responses in coniferous trees growing on natural soils, and might at first sight appear to be totally inapplicable to crop cultivation, nor do I claim that they are directly so applicable. The great advantage of them, as a starting point from which to consider the evidence in a wider field, is that while most of this other evidence is at best only circumstantial, though none the less cogent, the evidence of Rayner's experiments provide, in the case of certain important conclusions, critical scientific proof of so definite a nature as to preclude the possibility of doubt concerning the correctness of the deductions.

This being so, I felt that despite the specialized nature of the material under investigation at Wareham, here was a yardstick by which some of the scattered evidence covering a much wider field of material and conditions might perhaps be measured. My reasoning ran thus: In the course of Rayner's investigations on pines, certain soil treatments produced certain responses in the tree seedlings. The reasons for the results obtained were definitely and fully established. If it could be shown that similar treatments produced similar responses in crop plants on cultivated soils, then a prima facie case would have been made out for assuming that in both cases the same cause was operating.

I received early encouragement to pursue further this line of thought when I learned that the indigenous vegetation growing in the experimental area at Wareham did in fact respond to certain treatments in much the same way as the trees.

In the next chapter I shall develop further the hypothesis that an analogy exists between the Wareham experiments and crop cultivation. First I wish to describe two of the experiments themselves. The first proved that compost does not act like an ordinary manure by supplying nutrients to the pine roots direct (although this discovery when originally made was quite incidental to the work in hand), but that it acts indirectly by stimulating the activity of soil fungi. The second proved that the action of these fungi, in association with the pine roots, stimulated both root and shoot development in a manner far surpassing anything obtained by inorganic chemicals, this being demonstrated not only by the size of the tree seedlings under investigation, but also by their health and vigour, and powers of disease resistance.

I am greatly indebted to Dr. Rayner, and to the editor of *Forestry* (The Journal of the Society of Foresters of Great Britain) for permission to use abstracts and quotations from the papers describing these experiments, and to reproduce some of the photographs which illustrate them.

Dr. Rayner is perhaps the first botanist to realize that the question of the exact function of mycorrhizal association in trees, so long a matter of controversy, can never be finally answered in the laboratory.

'Modern research on mycorrhizal problems has been marked by recognition of the extraordinary frequency of the phenomenon in nature and by the application of more precise methods of research involving isolation and pure culture of the fungi concerned. Investigations of this kind are laborious; extraction of the mycorrhizal fungi and the synthesis of fungus and host in pure culture present difficulties, while evidence of behaviour under fully controlled conditions must be applied with the greatest caution to those in nature. The mycorrhizal habit, possibly of critical importance to plants exposed to full competition in the field, may play an insignificant part in the nutrition of the same species sheltered from such competition. For the latter, the rooting conditions are relatively simple and static; to the former they must present a succession of complex and continually shifting problems complicated by the direct competition of other soil organisms for food materials, and also indirectly by changes in the environment conditioned by these and other microbiological activities.' (Rayner, *Forestry,* 1939.)

Holding these views, it was only natural that Rayner should be on the look-out for opportunities of conducting research on mycorrhizal reaction under natural conditions, and of supplementing laboratory tests by field tests.

An admirable opportunity occurred in connection with the afforestation under the Forestry Commission of a tract of 3,454 acres of very poor infertile land at Wareham Forest in Dorset.

The early attempts at tree planting there had met with very irregular results, a large proportion of the seedlings having died outright or passed into a condition of 'more or less complete check'. Rayner records that 'It is still possible 14-16 years after these original sowings, to find surviving seedlings a few inches high. The root systems of such plants from untreated soil even when quite young, were defective, with intermittent die back of the younger roots, and corresponding poverty of mycorrhizas.' (Rayner, *Forestry,* 1939.)

In 1930 Rayner began her series of researches into the cause of infertility for tree growth in the Wareham soil. She formed the opinion that in those places where tree growth was inhibited a toxic factor in the soil was operating. This view was subsequently proved to be correct by independent investigation and the toxin was shown to be of biological origin. (Professor Neilson-Jones, 'Biological Aspects of Soil Fertility', *Journal of Agricultural Research,* Vol. 31, Part 4, October 1941. (See also Chapter V and Bibliography.) This peculiarity in the Wareham soil greatly facilitated the investigation. One of the factors adding to the difficulty of mycorrhizal research under natural conditions is the liability of roots to suffer attack by parasitic fungi, when conditions favouring mycorrhizal association are upset. In untreated Wareham soil *all* fungal growth is more or less inhibited, and thus experiments designed to determine mycorrhizal responses were exceptionally free from any confusing issues.

The earlier experiments at Wareham proved conclusively that mycorrhizal association in pine is causally related with healthy growth, and experimental soil treatments were designed to ameliorate the conditions believed to be responsible for inhibition of fungal activity, and ultimately for defective root growth of the pines sown or planted in the area. Chief among the treatments adopted by Rayner to this end was the use of different kinds of carefully prepared organic composts. The results were startling. (See Plates III-V.) They were published in the 1936 issue of the *Journal,* and caused a flutter in forestry circles; also some controversy, for while the results of her treatment could not be disputed--they were there for all to see--her conclusions were not always accepted. At that time proof was still lacking of the correctness of her initial hypothesis of the biological origin of soil infertility at Wareham, and it was argued that it was the chemical nutrients in the composts that affected the growth of the trees, and not their effect upon biological soil activities. An experiment was therefore designed as an answer to this criticism.

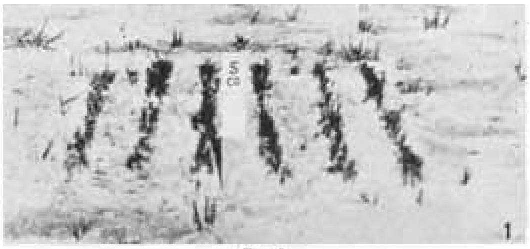


Fig. 1

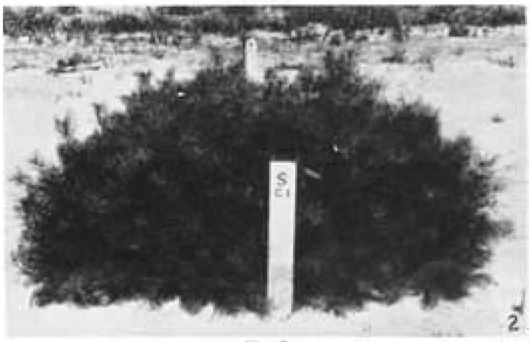


Fig. 2

Fig. 3

PLATE III. Experimental Field Plots at Wareham Forest, Dorset. Scots Pine, sown April, 1933, photographed July, 1935. *Fig.* 1 Control plot untreated. *Fig.* 2. Plot treated 10 lb. compost *C*1. *Fig.* 3. Plot treated 10 lb. compost *C*5. All from more exposed area.

Plates III to X reproduced by the courtesy of the Editor of Forestry

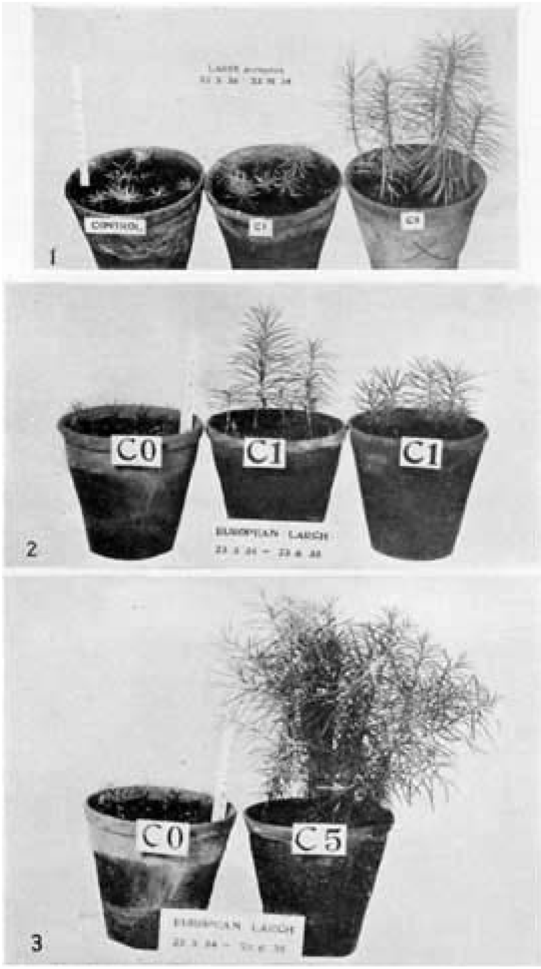


PLATE IV. *Fig. 1.* 7 months from sowing. *Figs.* 2 and 3. 15 months from sowing. *Fig.* 1 shows representative pots of controls *(C_0)* and plants treated C_1 and C_5 respectively; at this age condition in each series was uniform. *Fig.* 2. Representative pots of controls and plants treated C_1; all pots uniform within series. *Fig.* 3. Representative pots of controls and plants treated C_5. Controls uniform in all pots of series; range of variations in treated plants illustrated.

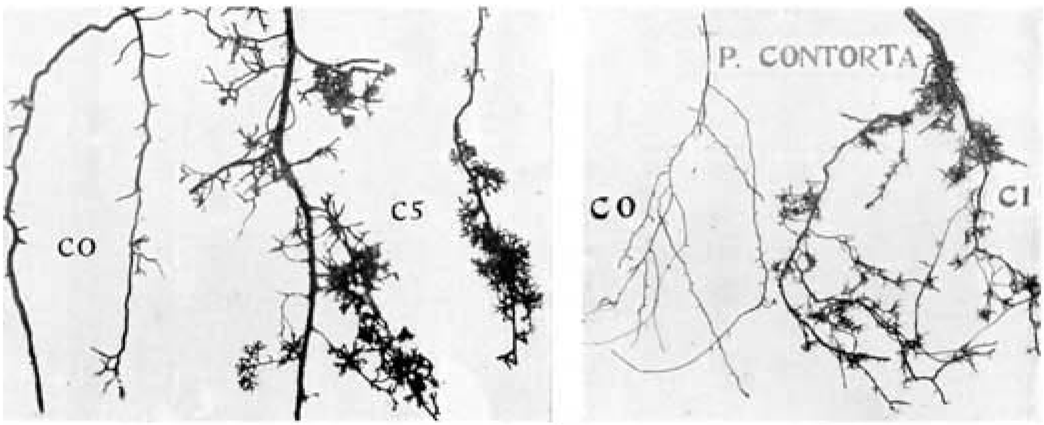


PLATE V. *Fig.* 1. Lodgepole Pine (*Pinus Contorta*) roots from untreated soil (C_0) and from soil treated with C_5 compost (field plot). *Fig.* 2. Ditto, roots from untreated soil (C_0) and from soil treated with C_1 compost (pot cultures).

Field observations had already indicated the complex nature of compost action. For example, tests were made with two composts of almost exactly similar appearance and chemical composition. One was made with 75 per cent softwood sawdust and 25 per cent fallen beech leaves, and the other with 75 per cent softwood sawdust and 25 per cent chopped straw, both were composted with 1 per cent of nitrogen in the form of dried blood. When these were applied to field sowings of Scots pine, the first produced 'well-balanced, vigorous growth with free development of mycorrhizas of normal structure', while the second produced results 'little better than the untreated controls'. Yet the same two composts when applied to another species of pine (*Pinus Contorta*) both produced equally vigorous growth, in marked contrast to the controls.

The whole of the experimental area suffers from a marked phosphate deficiency., and the application of phosphate in certain forms (notably basic slag and bone meal) has brought about effects in kind similar to that induced by compost treatment, though the *extent* of growth stimulation is greater with composts (see Plates VI and VII). On the other hand phosphate applied in some other forms, superphosphate for instance, proved lethal to the trees.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

PLATES VI AND VII. Wareham Forest, Dorset. Comparative effects produced by two composts (*C*1 and *C*5) and Basic Slag on field sowings of Corsican pine. Photographs at representative patches 17 months from sowing. *Fig.* 1. Control untreated. *Fig.* 2. Treated 2 oz. basic slag at sowing. *Fig.* 3. Treated 2 lb. of *C*1 compost at sowing. *Fig.* 4. Treated 2 lb. *C*5 compost at sowing.

These various observations are held to support the view that compost, and very probably phosphate also when applied in the form of basic slag or bone meal, act indirectly, and that their organic constitution, and their effect on the soil micro-flora, are more critically important to the growth of conifers, than the quantity of available nutrients which they may contain. In order to put this hypothesis to the test the following experiment was carried out.' See *Forestry,* 1939 issue, or *Problems in Tree Nutrition,* Faber and Faber.)

Several series of pot sowings of Scots pine were made in imported Wareham soil. In two series, two different composts (C 1 and C 5) were added at the time of sowing. Two other series received the amount of salts needed to supply nitrogen, potash, phosphoric acid, and lime, in the same quantities as those present in the compost. (For exact analyses, and details of technique, see Technical Ref. No. 5b p. 235.) A fifth series was sown in the experimental soil with cow manure added at the same rate as the compost. The control series consisted of sowings in the experimental soil without any addition.

C 5 compost is made from hop waste, and C 1 compost from chopped straw. In this experiment both were composted with 1 percent nitrogen in the form of dried blood.

All series were run in two alternative ways. In one group any excess of water which drained from the pots was discarded. In the other it was collected in darkened containers, in which the pots stood, and was regularly returned again to the pots. In this second group, therefore, no soluble nutrients were lost through leaching. The plants were watered with rain water throughout the experiment which lasted for two years.

Rayner reports that all cultures were 'entirely satisfactory in respect to health of the seedlings, uniformity of growth within each series, and range of variation within the populations of individual pots.'

At the end of the first year's growth control seedlings in the untreated Wareham soil 'made defective root and shoot growth and produced short needles of a bad colour'. The series receiving equivalent salts were 'quite healthy and vigorous' but were markedly smaller than the plants of either composted series. (See Plate VIII, top.) Both these last made much more growth than any of the other series, the maximum being obtained with C 5 compost. In both, 'shoot and root development were greater, needles longer and of better colour'.

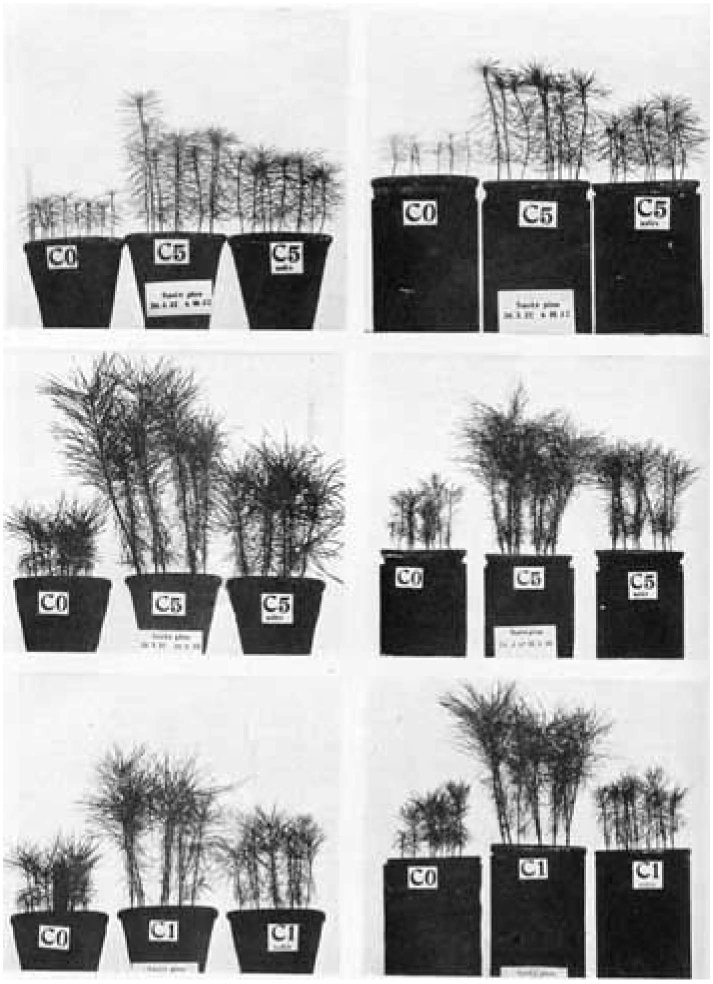


PLATE VIII. C_0Wareham soil untreated. C_5 same plus 25% C_5 compost. C_5 salts. same plus equivalent nutrient salts of C_5. C_1 same plus 25% C_1 compost. C_1 salts. same plus equivalent nutrient salts of C_1. *Group* 1. Drainage not returned, on left.

Group 2. Drainage returned, on right. *Top:* six months from sowing. *Middle and bottom:* 18 months from sowing.

There was very little difference in any of the series between the two groups, one with and one without having the drainage water returned. During the second season the differences in growth between the various series was maintained. (See Plate VIII, middle and bottom.) But by the end of that year when the experiment was brought to an end, a marked difference had become apparent within the different series between the groups receiving and not receiving the return drainage water. This affected not only the size but also the health and vigour of the seedlings.

In the case of the compost treated plants, and those with cow manure, the return of drainage water proved to be beneficial, the dry weights of the seedlings in these series, exceeding those of the same series in the group not receiving the drainage water by from 2.2 per cent in the case of cow manure up to 1221 per cent in the case of C 5 compost. In the case of the control seedlings in untreated soil and those receiving equivalent salts, the reverse effect was apparent. Here return of the drainage water proved to be deleterious. In this case the dry weights of the seedlings in these series were less than the same series in the group not receiving the return drainage water, by amounts ranging from 23.7 per cent in the case of C 5 salts up to 32.5 per cent in the case of the controls.

A further interesting point was noted, the increases and decreases in the dry weights were calculated separately for the root and shoot systems and it was found that where the return of the drainage was beneficial, the increase in dry weight was greatest in the case of the root system, whereas in those series where the return drainage proved to be deleterious the decreases in dry weights were greatest in the shoot system.

The detailed table of weights is given in Technical reference No. 5c. Tables 3 and 3A give a summary.

TABLE 3

WHERE RETURN DRAINAGE WATER WAS BENEFICIAL

	Increase weight percentages	
	Shoot	Root
Wareham Soil + C 5 compost	6.5	20.2
Wareham Soil + C 1 compost	.7 2	0.3
Wareham Soil + Cow Manure	1.8	3.4

TABLE 3A

WHERE RETURN DRAINAGE WATER WAS DELETERIOUS

	Decrease weight Percentages	
	Shoot	Root
Wareham Soil untreated	37.3	20
Wareham Soil + C 5 equivalent salts	25.8	17.8
Wareham Soil + C 1 equivalent salts	27.3	24.5

Rayner's observations on this result are as follows:

'The presence of soil substances actively inimical to root growth was inferred at an early stage of the Wareham researches. It was, indeed, the conclusion derived from this inference, that the marked infertility of this soil for tree growth is more closely related to the presence of such toxic substances than to poverty of nutrients, that led originally to the use of organic composts as a means of alleviating the unfavourable condition.

'In view of the purpose of the present experiments, however, it is regarded as highly significant that return of drainage water over considerable periods has provided evidence of a depressing effect upon growth, far exceeding in magnitude any beneficial effect derived from return of leached nutrients, in all cases except those in which the soil received additions of organic matter in the form of composts or cow manure. The results of the present experiments thus confirm conclusions already reached in respect to the existence of deleterious substances in the soil solution, and clarify previous observations on the beneficial effects of leaching in pot cultures. Not only so, but they afford convincing evidence in support of the hypothesis that compost treatments operate mainly by bringing about fundamental changes in the organic residues, whereby the microbiological activities of the soil and their ultimate by-products are profoundly and permanently modified.

'The experiments show that increase in the supply of available nutrients plays a relatively insignificant role in the steady maintenance of healthy and vigorous growth that follows addition of composts to the soil. They show further that addition of mineral salts is practically without influence on the production of substances deleterious to growth, whereas that of composts--and to a less extent of cow manure--puts a stop to the production of undesirable by-products, thereby rendering the leachings innocuous and permitting utilization of any nutrients returned with them.'

Examination of the root systems for mycorrhizal reaction at the end of the experimental period showed that in these pot experiments, 'All plants showing maximum size, health and vigour, showed also a maximum development of mycorrhizal fungi.' (Space does not permit the inclusion of a detailed description of the mycorrhizal responses in the different series of this experiment. Readers are referred to Dr. Rayner's paper in the 1939 issue of *Forestry* which is published as a reprint by the Oxford University Press, or to her book *Problems in Tree Nutrition,* Faber and Faber.)

Discussing the results of this experiment Rayner writes:

'The experiments described in this paper were designed to meet the criticism that addition of mineral nutrients to the soil, in amounts corresponding to those in composts, would produce similar effects on growth, and to establish the correctness of conclusions put forward in an earlier communication. For the soil under investigation, these conclusions were that the use of organic composts produced qualitative changes in the humus constituents and that these, rather than increase in the supply of available nutrients, are the fundamental cause of restored fertility. The failure of growth and irregularity of behaviour observed in the trees were interpreted as bound up with biological activities yielding inimical by-products, and not merely as a resultance of poverty in available nutrients.

'The evidence derived from the pot-cultures in Series 2, 3, 4 and 5 of the present experiments affords direct support for this hypothesis of compost action. It proves that increasing the supply of nutrients in this poor soil by addition of soluble salts of nitrogen, potash, and phosphoric acid, corresponding in amounts to those in the composts, evokes surprisingly little response in pine seedlings, even when potential loss by leaching is compensated for by return of all drainage throughout the period of the experiment. It thus provides a complete refutation of the criticism that the action of the composts in promoting the healthy growth of young trees on certain soils is mainly due to increased supply of directly available nutrients, confirming the conclusion that the action of the compost in stimulating the growth of pine seedlings differs essentially from that of ordinary manures. . . .'

I have described this experiment in some detail, because the point which it emphasizes cannot be too often repeated, namely, that the value of compost as a treatment for crops cannot be measured only, or even mainly, in terms of its chemical composition.

It may be argued that no such general deduction can be made from the results of experiments carried out on conifers, and on a soil type so extreme as that at Wareham. I offer my answer to this possible criticism in the next chapter, when the whole question of the wider application of the Wareham experiments will be considered. At this point I go no farther than to assert that in so far as the pine seedlings under consideration were concerned, the experiment just described definitely established the claim that compost does not act like an ordinary manure. Further, it demonstrated that while compost possesses the power to remove factors inhibiting fungal activity, continued application of nutrients in the form of chemical salts does not.

That mycorrhizal activity follows the application of compost was proved by examination of the root systems concerned. That this increased activity was due to stimulation of the fungi already present, and not to active mycelium introduced with the compost was proved by the fact that mycorrhizal activity was also found to follow applications of sterilized compost.

Although these vigorous mycorrhizas formed by healthy seedlings treated with compost show marked structural differences from those growing in untreated soil, there is no question of a different fungus being responsible. In natural Wareham soil only one species of fungus has ever been observed as forming association with Scots pine.

'All mycorrhizas, whether normal in structure or otherwise, are formed by association with *B. bovinus* identified in the case of each type by isolation of the mycelium and comparative study in pure culture.'

We now come to the second point. The series of experiments which established the fact that it was the stimulation of the mycorrhizal fungus, by whatever means induced, that was responsible for the restored fertility. Proof of this has been supplied by a series of experiments, the results of which are described in a paper by Rayner and Levisohn published in the 1941 issue of *Forestry.* (Reprinted in *Problems in Tree Nutrition,* Faber and Faber.) These experiments took the form of isolating the mycelium responsible at Wareham for the formation of mycorrhizas in pine, and then using different forms of the pure fungus in a series of soil inoculations. Tests were also made with humus inoculations.

These investigations were carried out both in field plots and in pot experiments. In the latter, the sequence of events already observed in compost treated plants followed in all cases, whether the inoculum employed consisted of pieces of natural sporophores, fragments of humus from suitable soil (see Plate IX), or pure fungus culture raised on laboratory media. In all these cases inoculation was followed by development of the short root system of the seedlings, and the subsequent rapid conversion of these roots into mycorrhizas. A marked improvement in the health and growth of the seedlings then took place.

PLATE IX. *Fig.* 1. Lodgepole pine. *A* Wareham soil. *B* ditto plus 5 gm. inoculum of Californian soil. *C* soil from E1 Dorado National Forest California, all 13 months from sowing. *Fig.* 2. Norway spruce. *C*0 Wareham soil untreated. *C*1 ditto plus *C*1 compost. 18 months from sowing. *Fig.* 3. ditto. Right-hand pot, Wareham soil plus 5 gm. inoculum Swedish soil. Left-hand pot Wareham soil plus *C*1 compost plus 5 gm. inoculum Swedish soil. 18 months from sowing. *Fig.* 4. ditto. *C*0 (left) Wareham soil untreated. *C*0 (centre) Wareham soil plus 5 gm. inoculum of Swedish soil. *C*5 Wareham soil plus *C*5 compost plus 5 gm. inoculum Swedish soil, all 27 months from sowing.

In the field plot experiments the inocula were inserted here and there throughout the plots, a few inches below the surface. In this series of investigations the resulting responses were much more variable than in the pot experiments, but in all cases an improvement in growth as compared with the controls took place, though in some of the pure culture inoculations this was considerably delayed.

Plate X illustrates the results on one of these plots.

Fig. 1

Fig. 2

PLATE X. *Fig.* 1. Scots pine control seed plot, Wareham experimental area, untreated soil. *Fig.* 2. Ditto, seed plot Wareham experimental area, treated with inoculum of *Bolitus Bovinus* in pure culture 14 months from sowing. Both photographs 8 years from sowing and on same scale.

In these field plot inoculation experiments, the improvement in the health and growth of the seedlings in the plots treated began with those growing nearest the points of inoculation, and gradually spread outwards from them, through the plot. Stimulus to growth must therefore 'originate in these inocula and is evidently biological in character. . . . It is legitimate to infer that the biological constituent concerned in all these cases is mycelium of a fungus or fungi known to form mycorrhizas with the tree species under observation; known to be introduced in the inoculum and observed to be present in the mycorrhizas subsequently developed. . . . The conclusion follows, therefore, that soil activities leading to the stimulation of plant growth are induced by the introduction to seed-beds of suitable inocula, whether of soil fragments or sporophore tissue, or pure cultures of specific mycorrhiza-formers,' and 'This stimulus to root production is directly related in some manner-at present unexplained-to the results of fungal activity in the soil.' (For detailed technique of this experiment the reader is again referred to *Forestry,* 1939 issue, or *Problems in Tree Nutrition,* Faber and Faber.)

As a result of the two series of investigations just described, it must be conceded that in the case of pine seedlings grown on Wareham soil, the following facts are fully established.

(*a*) Compost treatment produces healthy growth absent in the controls.

(*b*) This is not due to the available plant nutrients contained in the compost.

(*c*) Nutrients supplied in the form of inorganic salts fail to correct the toxic condition, and their continued application increases it.

(*d*) The vital factor governing restored fertility is stimulation of mycelial activity.

Before proceeding to the next step in the building up of my case there is one more of the Wareham results which must be mentioned. This is concerned with observations made on Lawson's cypress. This conifer, unlike pines and spruces, forms endotrophic mycorrhizas in common with ordinary crop plants (see Plate II, Fig. 4). It is a native of the northern Pacific States of the U.S.A. and is commonly planted as an ornamental tree in gardens in this country. It is 'not fastidious in respect to soil and climate under these conditions'. (Rayner, *Forestry,* 1941.)

During the earlier afforestation attempts at Wareham a few experimental plantings of this tree were made there. The seedlings used were transplants from nursery soil. Some were transplanted into untreated Wareham soil, others received 2 oz. of basic slag at the time of planting. When Dr. Rayner's attention was first drawn to these seedlings, four years after planting, they were 'conspicuous for the vigorous growth made on very poor light soil . . . both the control plants and those that had received phosphate were equally healthy and vigorous; in both the foliage was green, and there were no symptoms of malnutrition.'

This behaviour was so surprising in view of the natural habitat of this tree, and so at variance with the usual experience at Wareham, that an examination was undertaken of the root systems of seedlings growing at Wareham, of others in the original nursery soil, and of a third series sent from Oregon, U.S.A.

In plants from all these sources 'the whole root system including the young active roots proved to be mycorrhizal, showing deep-seated infection by the mycelium of a fungus of the vesicular-arbuscular type'. Pot sowings were then undertaken in order to find out if this fungus was ordinarily present in Wareham soil, or had been introduced with the transplants. One series was sown in untreated soil, two in soil receiving varying amounts of basic slag, and another series in soil plus an addition of C 5 compost. Here are the results. The controls in untreated soil were 'very small with poor root development and discoloured foliage. Addition of basic slag at the rate of 5 grammes or more per pot was deleterious to growth; at the rate of 2 grammes per pot produced no detectable effect. Addition of C 5 compost gave marked improvement of growth comparable with that already observed for pines and other conifers. In none of the experimental plants was any trace of mycorrhizal infection present.' This result was later confirmed by further experiments. The fungus had thus clearly been introduced with the transplants.

The sequel to the story is particularly interesting. In 1939 the cypress seedlings growing at Wareham began to show signs of ill health: first yellowing of the foliage and then cessation of growth. Laboratory examination of the roots of these plants revealed that 'mycorrhizal association had disappeared from the roots of the plants treated with basic slag, and was present only as traces of fungal infection locally in those of the control plants.'

Obviously mycorrhizal association plays a critical part in the normal nutrition of this tree. The two most interesting points in this investigation seem to me to be: (*a*) that while the fungal associate of this cypress (a forest tree in its native U.S.A.), clearly does not exist in Wareham soil, it does presumably exist in the garden soils of this country; and (*b*) that in the pot experiments the seedlings made healthy growth in the presence of compost even without forming mycorrhizal association.

In connection with this, an interesting thing occurred last winter (1941-2). Dr. Rayner tells me that in the course of a pot experiment with seedlings of this cypress, it was found necessary (not as part of the experiment) to let the pots stay out of doors all the winter. As most of us are not likely to forget, it proved to be the hardest winter known in this country for many years. The severe frost proved to be too much for the pot seedlings growing in untreated Wareham soil, or in soil with an addition of basic slag; the plants growing in compost-treated soil on the contrary, not only survived the winter, but remained outstandingly robust and healthy. (See Chapter VIII for a similar experience with beans.)

Tests are now being made at Wareham with this tree to determine whether applications of compost at the time of planting will maintain the activity of the associate fungus introduced with the transplants, and further tests are being made to discover whether this cypress can continue to thrive without its fungus if compost treatment is given. I await the results of these further experiments with lively interest, for I feel that Lawson's cypress, which, like crop plants, forms endotrophic mycorrhizas, may afford a link to bridge the gap in the present knowledge of the latter.

The knowledge which has been accumulated in respect to the ectotrophic mycorrhizal habit in trees is now very extensive, as this chapter must have indicated. The endotrophic mycorrhizal habit in crop plants on the other hand has been shockingly neglected. ('The part played in nutrition by the fungi present in endotrophic mycorrhizas, and the biological significance of root infection in relation to differences of soil and other external factors, continues to be a subject of controversy. There is a strong prima facie case for a beneficent action upon the nutrition of the host based upon cytological and microchemical evidence. To supplement this, data derived from pure culture experimental researches on certain groups is now slowly accumulating.' See also Technical Ref. No. 6.) The fact that trees are long-term plants, so that seedlings can be observed over several years growth has, no doubt, made them easier to study, and therefore more attractive to research workers. The ordinary crop plant which reaches maturity in a single season must obviously present greater difficulties to the would-be observer. This is where I feel that a study of Lawson's cypress may be of assistance. If this tree should prove capable of survival without mycorrhizal association in compost-treated soil, then a close study of its behaviour might lead to an explanation of the undoubted fact that on species of crop plants not believed to form mycorrhizal association, (For example, members of the cabbage family.) compost treatment often produces results as spectacular as those resulting from the same treatment on known mycorrhiza formers.

This is an important point sometimes lost sight of. It will be more fully considered in the next chapter.

CHAPTER V
CIRCUMSTANTIAL EVIDENCE

'Nature is often greatest in her smallest creations.'
M. S. Devere

In this chapter I undertook to show that a connection exists between Dr. Rayner's research work on coniferous trees at Wareham Forest, and the everyday cultivation of food crops.

In order to marshal the evidence in an orderly fashion, I will now recapitulate under six headings certain facts proved at Wareham. I then propose to take these six points in order, and to see if any evidence exists for believing that to any, or all of them, a parallel can be found in ordinary farming practice.

Here is the list:

(1) Mycorrhizal association plays a critical part in the nutrition of pines, the fungal activity producing substances that stimulate the growth of lateral roots.

(2) Infertility for tree growth at Wareham is not due to absence of the appropriate associate fungus, but to a toxic condition which inhibits all mycelial growth. This toxin is of biological origin, being a by-product of the metabolism of some soil organism.

(3) The application of nutrient salts of nitrogen, phosphorus, and potash, fail to alleviate the toxic condition, the relatively small improvement in growth of the seedlings resulting from their application not being maintained.

(4) The application of composts made by fermenting vegetable wastes with 1 per cent of nitrogen in the form of dried blood, not only rapidly removes the toxic condition, but is self-propagating in that the soil so treated does not regain toxicity. This result is not obtained in so great degree when an inorganic chemical activator is substituted for the dried blood.

(5) The action of the compost is not due to the plant nutrients it contains, but to its biological reaction which has the effect of fundamentally modifying the soil microflora.

(6) The restoration of health and vigour in the pine seedlings, brought about by compost treatment, is not due to direct action of the compost on the plant roots, but to indirect action due to stimulation of mycorrhizal and other soil fungi, and the removal of the substance previously inhibiting their growth.

These six points were *proved* in so far as the particular case of tree growth in Wareham soil is concerned. On the extent to which they can now be shown to apply also to other soils and crops, depends their importance to farming practice, and national health. Taking these points in order then, the first question to be answered is this: Does mycorrhizal association play a vital part in the nutrition of other mycorrhiza formers growing on ordinary soils? If so, in what does the benefit to the host plant consist?

The following is the opinion of a Professor of Botany on this point 'The plant physiologist is simplifying unduly the problem with which a plant growing in soil is faced in obtaining nutrients by means of its roots, if it be assumed that conditions approximate to those of experimental laboratory cultures in which mineral salts are supplied to the roots for absorption. In soil, the activities of various micro-organisms complicate the natural roots' environment in many ways: not only by direct competition but by controlling the forms in which available nutrients are presented and the production of substances beneficial or deleterious to growth; also, by forming beneficent or harmful associations with the root tissues. The fact that probably 80 per cent of flowering plants form mycorrhizal relationships is alone sufficient to suggest that the simple picture of mineral salts absorbed through root hairs represents only part of the mechanism of root nutrition--in many cases quite a small part of all the processes intervening between addition of organic matter to the soil and absorption of nutriment by the plant. Presumably, the difficulty of precise quantitative investigation of the nutritive relations of mycotrophic plants is responsible for retention of the convenient fiction that this form of nutrition is casual and exceptional, when in point of fact it appears to be normal and regular for a majority of mature flowering plants in soil.' (Neilson-Jones, 'Biological Aspects of Soil Fertility'. *Journal of Agricultural Research,* Vol. 31, Part 4, October 1941.)

In a pamphlet, printed in 1939, of which this book is really an enlarged and revised edition, I suggested that the part played by mycorrhizal fungi in forming a bridge between humus in the soil and the roots of plants, was a discovery of very recent origin.

It will be seen from the previous chapter that this is not factually correct, Frank having held the view, as long ago as 1885, that 'Mycorrhiza is a symbiotic relation to which probably all trees under certain conditions are subject. It is formed only on soils containing humus or abundant plant remains, and its formation waxes and wanes with the abundance or otherwise of these constituents in soil. The root fungi carry to the trees not only the necessary water and salts but also soluble organic material derived from the humus, thus lending a new significance to leaf-fall and the accumulation of humus in woodland soils.' (Rayner, *Mycorrhiza.*)

But even though this discovery was made by 1885, I still do not feel inclined to retract my original statement, for while it may not be true in the letter, I maintain that it is true in the spirit. In support of this view I again refer to the inadequate treatment of the subject in textbooks, and agricultural teaching. Although research work on mycorrhizal responses has been going on for 100 years, it has been principally confined to trees, orchids, and heaths, and mainly conducted in the laboratory. That the possible importance of the habit in ordinary crop plants has been largely overlooked is clearly shown by the first of the above quotations. Not till Rayner's field experiments demonstrated the connection between compost treatment and mycorrhizal responses in trees, was the clue apparent to explain results being obtained, by some other users of compost, on crop plants.

The clue may have been on record for close on 100 years, but Rayner presented it in a new light, and Howard had the brain-wave to see where it led.

How new was this light, is proved by the fact that it was found necessary to arrange a special experiment in order to demonstrate that the beneficent effect of compost bears little relation to its chemical composition, and that its biological reactions are of more importance than either its physical properties or the plant nutrients which it may contain.

As already explained, this elucidation by Rayner of the complete nature of compost action, including its ability 'to alter profoundly the soil bionomics', was quite incidental; her compost treatments, conceived for a special purpose, having no relevance to 'compost experiments' in the usual sense. It is for this very reason that it required something in the nature of an inspiration on Howard's part to see a connection between the forestry experiments at Wareham, and certain results being obtained in India on tropical crops.

This is how he himself describes this discovery:

'How does humus affect the crop generally and how does a factor like this increase resistance to disease? The large scale trials of the Indore process now being carried out on coffee, rubber, cacao, and other crops in the tropics have furnished some interesting information on these questions.

'In a number of cases, in tea and rubber in particular, very striking results followed closely on *one* dressing of compost applied at the rate of five tons to the acre. There was a marked improvement in growth and also in the resistance to insect pests such as red spider, Tortrix and mosquito blight (Helopeltis). Two applications of compost have also transformed a derelict tea garden into something above the average of the locality.

'In a recent tour of tea estates in India and Ceylon I have seen these results for myself, and have discussed matters on the spot with the men who have obtained them.

'When these cases were first brought to my notice towards the end of 1936 and during 1937, I found considerable difficulty in understanding them. If humus acts as an indirect manure by (1) recreating the crumb structure and so improving the tilth, and (2) by furnishing the soil population with food from the use of which the soil solution eventually becomes enriched to the advantage of the crop, such factors would take time and we should expect the results, if any, to be slow. The improvement following humus was the reverse of slow-it was immediate and spectacular. Some other factor besides soil fertility appeared, therefore, to be at work.

'After much thought it occurred to me that the explanation would be found in the active root system of tea and rubber, and that the remarkable results recently obtained by Dr. M. C. Rayner on mycorrhiza in relation to forestry at Wareham in Dorset would apply to tropical crops.

'The simplest and most obvious explanation of the sudden improvement after one application of compost is the well-known effect of humus in stimulating the mycorrhiza which are known to occur in the absorbing roots of tea, and which in all probability are to be found in rubber, coffee, and other cultivated plants in the tropics.'

Howard's realization that mycorrhizal association might be a key factor in the proper nutrition of a very much larger range of plants than had hitherto been suspected, led to the careful examination of the roots of a large number of crop plants of both tropical and temperate climates. This revealed that a very large number indeed are mycorrhiza formers. The examinations were carried out by Dr. Rayner and her assistant Dr. Levisohn. A surprising parallel to the Wareham experience resulted.

In all the specimens examined vigorous healthy growth was invariably accompanied by extensive fungus infection of the roots of the plants concerned. This was defective or absent when the plants were poor and unhealthy. Crops grown with compost, or ample quantities of farmyard manure always showed maximum mycorrhizal development, in marked contrast to those grown with artificials.

In a circular letter to correspondents dated 15th July 1938, Howard lists some of the crops examined with the following notes on their reaction to different soil treatments.

'(1) *Cotton.* The Indian cotton crop provides an interesting pointer on the relation between a fetrtile soil and disease resistance and quality. In Central and South India thousands of examples of intensive cotton growing exist in the zones of highly manured land round the villages. Here cotton always does well and there is practically no disease: the yield and quality of the fibre are satisfactory. Surrounding these areas are stretches of extensively farmed land low in organic matter where the yield is uncertain, the quality average and the damage done by various pests often considerable.

'Many attempts have been made to increase the crop by means of artificial manures but the results I have seen have never been quite convincing: the benefits following chemical manures are not the same as those conferred by a fertile soil. If cotton is a mycorrhiza-former these differences would be explained. The mycorrhizal relationship would provide channels of sustenance between a soil rich in organic matter and the plant. The first of the appended reprints shows that cotton, like tea, is a mycorrhiza-former. In this note the bearing of this fact on production and future research is explained: the investigations of to-morrow in cotton will have to start from a new base line-soil fertility. Very much the same considerations apply to future research on tea.

'(2) *Grapes.* During a recent tour in the Midi some attention was given to the cultivation of the vine, a crop I studied for eight years on the western frontier of India. In the South of France grapes are raised very largely by means of artificials: the many diseases are combated by poison sprays.

'In Baluchistan, on the other hand, the vine is always manured with farmyard manure: artificials are not used: the crops have no need of fungicides and insecticides because disease is practically non-existent.

'On one occasion only near the village of Jouques, Bouches du Rhône, did I come across vines which at all resembled the vigour and health of those to be seen on the western frontier.

'These were manured with pig manure and had never been treated with artificials: the yield was excellent and I was told the vineyard had an excellent reputation for quality.

'Specimens of surface roots were found to be heavily infected with mycorrhiza. This interesting bit of Nature's machinery is used to good effect by the tribesmen of Baluchistan; it is largely side-tracked by the cultivators of France.

'(3) *Hops.* Several of the merchants who handle the hop crop have assured me that the quality has deteriorated since artificials have come in and that really good quality hops can only be obtained by means of farmyard manure. Unquestionably the hop is much more liable to disease than it was in 1903-5 when I worked on this crop. In the course of some large scale trials of the Indore process at Bodiam in Sussex samples of the surface roots of this crop were found to be heavily infected with mycorrhiza.

'(4) *Sugar Cane.* As is well known, what amounts to a new sugar industry has arisen of late years in the plains of India as a result of the research work done at Shahjahanpur and Coimbatore--two Experiment Stations I helped to bring into existence.

'The splendid crops at Shahjahanpur were always raised on humus and were to all intents and purposes free from disease.

'This was my experience at Indore on the black soils where the Shahjahanpur methods were followed. Reports have recently reached me from India that where artificials are used the cane is being attacked by insect pests. If the sugar-cane is a mycorrhiza former, a simple explanation of these differences would be provided. The first set of cane roots obtained from Central India show that sugar-cane is a mycorrhiza former. Further examples from Louisiana, Brazil and Natal are expected shortly.

'(5) *Bananas.* The new banana industry of the West Indies is threatened with serious disease. In India I cultivated this crop successfully for some years and I also saw a good deal of the indigenous plantations. In all cases cattle manure was used and no disease trouble was ever brought to my notice. If the banana is a mycorrhiza former these results are understandable.

'The first set of banana roots I have just obtained from a rich garden soil in India shows abundant mycorrhizal infection.

'(6) *Strawberry.* The strawberry area near Southampton is rapidly contracting on account of poor soil conditions followed by disease. 'The small Experiment Station maintained by the Hampshire County Council at Botley is little more than a collection of pathological material. On the other hand commercial growers in this neighbourhood who use humus are getting satisfactory crops.

'Similar results are to be seen in South Lincolnshire and in other parts of England. Humus prepared from vegetable *and* animal wastes or farmyard manure produces healthy crops of good quality.

'The long continued use of artificials is followed by disease and indifferent fruit. The strawberry is a mycorrhiza former: the type of association being similar to that in tea. Subscribers interested in tea who grow strawberries can very easily compare the effect of humus and artificials on the health of the plants and on the quality of the fruit.

'These widely different examples--cotton, grapes, hops, sugar-cane, bananas and strawberries--tell the same story and afford interesting confirmation of the views in the report on my recent tour of tea estates in India and Ceylon. Nature has gone to the trouble of creating a link between humus in the soil and the plant. It behoves us to make the fullest use of this provision.'

Rayner summarizes her observations on one of these examinations--that of cotton--as follows:

'The cotton plant is a regular mycorrhiza former, infection taking place under favourable conditions at an early stage. The incidence of infection is closely correlated with the nature of the rooting medium and in the same soil varies markedly with different manurial treatments.

'Differential behaviour on the part of the endophyte was particularly well-marked in respect to applications of inorganic as compared with organic manures, and a response was also apparent following the use of different forms of organic manures.

'That these differences should be observable is in itself significant, and the relation of the incidence and character of mycorrhizal infection with the growth and vigour of the hosts under crop conditions is obviously worthy of close attention and study.

'The observations are in general agreement with those made on *Citrus* in southern California some years ago and are believed to justify similar conclusions.

'It is not proposed to discuss here the character of the symbiotic relationship in the type of mycorrhizal association represented in cotton. It is evident that it differs fundamentally from that in ordinary parasitic attack and that there exists in the arbuscular-sporangiolar and vesicular apparatus a mechanism capable of functioning for nutritive exchange. (See Technical Reference No. 6.) Coincidence of vigorous growth of the host with maximum infection may be observed in cotton as in other plants showing the same type of association, and this together with the histological evidence available supports the view that there is a substantial balance in favour of the vascular partner. Whether such exchange follows the lines elaborated by Frank and Stahl; whether it is concerned with major nutrients or takes a more subtle form such as that indicated in Butler's suggestion that "The vesicles and the arbuscular-sporangiolar apparatus are . . . mainly concerned with the accumulation of fatty material (possibly with accessory nutrients (See Technical Reference No. 6.)) and its transference to the higher plant," is, in my view, of secondary importance at this stage of the inquiry.

'The immediate point of interest incidental to the cultivation of cotton or other mycorrhiza formers is to confirm the view here put forward, that the fluctuations in mycorrhizal behaviour that undoubtedly occur are causally related with changes in the root environment brought about by manuring and other soil treatments and the responses of the host plants thereto.

'My interest in the matter has been stimulated by the opportunity recently provided to examine root material of a large number of species grown as crop plants both under tropical conditions and in the British Isles, among others, tea, coffee, sugar-cane, oil palm, coconut, cocoa, hops, vine. The conclusions now offered have been confirmed and strengthened by these observations. In all cases for which comparative material was available-including a majority of the samples--that collected from plants recorded as specially healthy and vigorous showed a maximum development of mycorrhizas with structural features believed to indicate a balanced relationship.

'It is not hereby suggested that in all cases of regular mycorrhizal association the habit is obligate or that some degree of mycotrophy is necessary for complete nutrition. The view held is rather that for species growing in nature the mycorrhizal condition in a healthy plant represents one of physiological equilibrium. Mycorrhizal association, often ignored or treated as an accidental and casual phenomenon, is a manifestation of biological soil activity, and as such cannot be profitably overlooked in the study of soil factors likely to promote healthy growth and maximum resistance to disease. . . .'

As already stated authorities are not agreed on the exact function of mycorrhizal association. Howard's view is that the root cells, acting very much like the stomach of an animal, obtain in the process of digesting the invading fungus, a protein food rich in nitrogen and phosphorus, and that:

'The mycorrhiza appears to be the machinery provided by Nature for the fungi living on humus in the soil to transmit direct to the active area of the roots the contents of their own cells. Whether this is the only means by which such things as accessory growth substances can safely pass from humus to plant, or whether the fungi provide essential materials for their manufacture in the plant itself, has yet to be determined with certainty. Some such explanation of what is taking place seems exceedingly probable. If the accessory growth substances contributed by humus were to pass from the soil organic matter into the pore spaces of the soil they would have to run the gauntlet of the intense oxidation processes going on in the water films which line these pore In this passage any substance of organic origin would be almost certain to be seized upon by the soil population for food and oxidized to simple substances, such as the plant ordinarily takes in by the root hairs. If, as seems almost certain, freshly prepared humus (obtained from animal and vegetable wastes) does contain growth-promoting substances (roughly corresponding to the vitamins in food), it would be necessary to get these into the plant undamaged and with the least possible delay.

'The mycorrhizal association in the roots, by which a rapid and protected passage for such substances is provided, seems to be one of Nature's ways of helping the plant to resist disease.'

There is no direct proof that this theory is correct, but it is an interesting hypothesis. It is now recognized that the inclusion of a proportion of fresh raw food in the diet of man and beast is the surest way of supplying those vitamins essential to the avoidance of malnutrition an the deficiency diseases caused thereby. (See Technical Reference No. 14.) Will this rule prove to apply als to plants? If so, the fact that disease should follow the under nourishment which would result from the omission of this living element from their diet, would be a perfectly logical sequence of events.

There is however a weak point in this theory, for it fails to explain the response to compost treatment of non-mycorrhiza formers.

It seems more likely that it is the action of soil fungi in general, which in some way--as yet unexplained--releases growth-promoting substances, and that mycorrhizal association is only one factor in the case though of prime importance to mycorrhiza formers. It seems clear tha this is the view which Rayner at present favours. Discussing the observed fact that introduction of active mycorrhizal material into the soil at Wareham was followed by an impetus to short root formation this root growth *preceding* infection by the fungus mycelium--she states:

'Of the exact nature of the stimulus to root production nothing is known; the term "growth-promoting substance" is used in a quite general sense. Nor is it known whether the capacity to bring about such stimulus to root production is limited to those fungal species capable of forming mycorrhizal associations. To the writers it appears improbable that this should be the case. . . .

'The view reached is that mycorrhizal association is a highly specialized aspect of the ecological balance normally maintained between the higher plants and their fungus competitors. The study of mycorrhizal association as an isolated phenomenon may obscure its real significance as an edaphic factor, a liaison aspect of soil bionomics linking the microbiological activities concerned in the maintenance of soil fertility with the nutrition of vascular plants. The specific bacterial and fungal associations exemplified in nodules and mycorrhizas are special cases of a complex ecological system embracing members of the surface vegetation and those of the soil microflora.'

The leguminous crops which form nodules in association with the bacteria referred to, and thereby are enabled to assimilate atmospheric nitrogen, may prove to be a fruitful field for further research into this question. All the members of this family that have been examined are also mycorrhiza formers, but with crop plants of this family, such as pulses and clovers, nodules and mycorrhizas *have never yet been noted on the same rootlets.* These have either formed nodules only, or mycorrhizas only, maximum development of the latter being associated with those plants showing also maximum vigour.

There seems little doubt that the health and quality of this group of plants suffer when mycorrhizal association is absent. Howard, writing on this point, states:

'A long experience of the cultivation of leguminous plants in India has completely shattered my belief in the idea that these crops can be grown successfully without organic matter, and that the nitrogen fixation in the nodules is the complete story as far as the supply of combined nitrogen is concerned. Farmyard manure or compost, as already stated, is essential for keeping these crops healthy and for making them form seed in the Indian Monsoon. Organic matter always stimulates both root and nodular development. . . .

'There is a further point of some interest in this matter. When plants like French beans are grown on poor soil by means of the nodules only, or by means of artificial manures, the produce is tasteless and of poor quality. For real taste and quality in the produce it is necessary to use humus (made from both vegetable *and* animal wastes) or farmyard manure. A supply of combined nitrogen appears therefore to reach the plant by way of nodules and root hairs; the materials which are needed for quality appear to be absorbed by the mycorrhiza.

'The leguminous plant therefore promises to be a very valuable instrument in separating out the various factors concerned in this question. Will, as seems to be the case, quality and disease resistance only be obtained when the mycorrhiza mechanism functions? Will disease resistance and quality turn out to be the same thing?' (Howard, 'Insects and Fungi in Agriculture', *Empire Cotton Growing Review,* 1938.)

It is of vital importance that a correct answer to this question should be found, but without waiting for the research which will assuredly one day provide it, one can go so far as to say, I think, that the evidence already submitted here, justifies the conclusion that mycorrhizal association is a habit that can no longer safely be ignored in the study of the nutrition of crop plants. Our first question has thus been answered in the affirmative.

The next three points on the list can be taken together. They all concern the toxic condition of Wareham soil. At first sight it would appear extremely improbable, if not impossible, that any parallel to this condition should be found in cultivated soils. Two things however are noteworthy, first, that while Wareham is an extreme case of its kind, its condition is one of degree rather than of essential peculiarity (Neilson-Jones, 'Biological Aspects of Soil Fertility', *Journal of Agriculaural Research,* Vol. 31, Part 4, October, 1941.) and second, that even in cultivated soils certain soil treatments have definitely been shown to depress mycorrhizal activity, and therefore it can be assumed that inhibition of fungal activity generally, *can* exist in such soils.

Our next question then, can be formulated thus: Does any evidence exist that where fungal activity is inhibited in cultivated soils a toxin may be operating of a kind comparable to that present in Wareham soil?

There can obviously be no great body of direct evidence on this point until many different soils have been subjected to the same type of intensive investigation as that carried out by Professor Neilson-Jones on Wareham soil, but a close study of his most interesting report of this investigation, notably in regard to some of the methods employed to increase and decrease toxicity, and a comparison of some of his results with certain causes and effects well known in farming practice, give rise to a not inconsiderable weight of circumstantial evidence. The Neilson-Jones experiments prove that the toxin indirectly inimical to the growth of higher plants in Wareham soil, is a by-product of some soil organism which operates directly by inhibiting fungal growth.

In the course of the investigation strong evidence was forthcoming that the organism concerned is anaerobic in habit. Waterlogging for example greatly increased the toxicity; partial sterilization by steaming for short periods, or by air drying, had the effect of inactivating the organism, but toxicity was regained when waterlogged conditions were restored. It required complete sterilization by steaming for an hour or more, baking under pressure, or soaking for long periods in alcohol to kill the organism. Soil so treated in the laboratory did not regain toxicity spontaneously under waterlogged conditions but required re-inoculation with untreated soil before doing so.

The identity of the organism responsible has not yet been definitely established, but the group of bacteria capable of reducing sulphates was suspected. This group was found to be present in Wareham soil in unusually large numbers. In the process of reducing sulphates these bacteria produce the poisonous gas sulphuretted hydrogen (H_2S). They can produce it either from sulphates applied as chemical salts, or from imperfectly decomposed organic matter, of which, as will presently be shown, there is also a high proportion in Wareham soil.

Although the presence of H_2S in Wareham soil has not been proved by direct chemical tests, all the observations and experiments made with soil samples in the laboratory are in conformity with the view that this gas may be responsible, at least in part, for the arrest of fungal growth. An account of one such experiment will suffice here.

'A series of cultures of once steamed soil was set up in flasks or Petri dishes of which half received an addition of 0.1 per cent NaCl (sodium chloride) solution, the remainder a corresponding addition of Na_2SO_4 (sodium sulphate) solution, each culture receiving sufficient to produce a waterlogged condition. A period of twelve days was allowed to elapse during which stimulation of the activity of H_2S-producing bacteria might take place, after which all cultures were exposed to air infection. A month later, all flasks that had received NaCl solution showed a profuse growth of *Mucor* spp. and *Penicillium* spp., whilst those that had received Na_2SO_4 solution showed either no mycelial growth or very sparse growth of *Penicillium* spp., any fungal development that had appeared in the earlier stages having retrogressed.

'The increased toxicity of soil to which sulphate is added is explicable if the toxicity is related in any way with a slow and continuous evolution of traces of H_2S derived from the activity of bacteria capable of reducing sulphates.'

Neilson-Jones adds that: 'This interpretation is purely speculative in that it is based on an isolated observation'; but he then proceeds to describe further tests and observations, all corroborating the one just described, in the course of which it was shown that the mycelium of airborne fungi 'is highly sensitive to H_2S, the smallest trace being sufficient to check growth.'

Many soils contain sulphur-reducing bacteria, particularly clay soils. It is well known to cultivators of clay soils that good crops usually follow a well-made bare fallow. Bare fallowing does not mean simply leaving a field derelict, as many laymen seem to think; it is, on the contrary, an expensive preparation for a subsequent crop, and consists of several ploughings, and constant surface cultivation throughout the summer. The effect of this, in addition to killing weeds, is to thoroughly air dry the top six or more inches of soil.

In his investigation on Wareham soil Neilson-Jones found that 'Air drying has an effect on soil somewhat similar to steaming: on remoistening the toxic reaction is found to have disappeared and mycelium grows as readily though with less vigour than on steamed soil. In fact, complete air drying may be regarded as a mild form of partial sterilization, the capacity of the soil for supporting a vigorous superficial fungal growth subsequently being due as with steamed soil, to the removal of the toxic reaction of the soil and the provision of an additional source of food--in this case presumably from the organisms killed by desiccation.'

There is an old saying that a bare fallow is as good as a coat of muck. (Bare fallowing is, of course, not suitable to all climates. Soil aeration is frequently best achieved by use of the wheel subsoiler and by growing deeprooting crops.) It appears that this may be literally true in that both have the power to discourage organisms capable of producing a toxin inimical to fungal growth, the difference being that the effects of one are temporary, while the other produces conditions which tend to be self-propagating and therefore permanent, or semi-permanent.

Here then, in two methods proved to be effective in removing the toxic reaction from Wareham soil, namely compost treatment and air drying, we have a close parallel in ordinary farm practice. Farmyard manure, and the bare fallow. What of the conditions shown to increase toxicity?

The deliberate waterlogging in the laboratory tests also has its counterpart on the land.

That it is impossible in ordinary farm practice to grow good crops on waterlogged land is a truism the reason for which is recognized as being a question of aeration.. Where the pore spaces in the soil are filled with water, air is excluded. 'Absorption by roots, being a process dependent on the action of living cells, is directly affected adversely by absence of oxygen,' but Neilson-Jones points out that 'a survey of the area at Wareham Forest made it clear that the inhibition of growth observed there was not due solely to such direct action. The work now recorded shows that factors of many kinds are concerned, and provides evidence that plant growth may be affected adversely or the reverse through causes inherent in the soil bionomics, members of the soil population showing great sensitiveness to aeration and to the nature of additions to the substrate whether derived from their own metabolic activities or from external sources.'

Once more we have to question whether this state of affairs is peculiar to Wareham soil. Here I think I can furnish some evidence from my own observation. I know a farm in Scotland, one lying in a notably fertile area, the land of which has been associated for generations with heavy crops, and noted for the excellence of its sheep and cattle. A few years ago this farm became part of a much larger unit the whole of which was turned over to mechanized farming. The live-stock disappeared, and in their place was seen the artificial manure distributor, and the harvester-combine. Temporary leys have recently been reintroduced on this farm, and a considerable head of livestock is once more being kept. But towards the end of its stockless period, although the land was still yielding heavy crops a definite increase took place in certain weeds usually associated with water-logged soils, or soils with a pan. Now on this land the appearance of these weeds is certainly not due either to bad cultivation or to waterlogging, nevertheless a condition is developing which points to faulty aeration. What is the factor, or factors, responsible? Possibly they include a reduction in the earthworm population. This usually occurs where artificials have been substituted for farmyard manure, and earthworms are great soil aeraters. (See Chapter VI, also Technical Ref. No. 8.) Conditions inimical to earthworms are equally unfavourable to fungal activity. Both worms and fungi appear to be highly sensitive to certain chemical salts (See Chapter VI, also Technical Ref. No. 8.) notably sulphate of ammonia. It seems a plausible hypothesis therefore, that the appearance of conditions suggesting faulty soil aeration may be connected with poisonous products resulting from the interaction between sulphate reducing bacteria and ammonium sulphate applied as fertilizer.

In stockless farming I am told that the bare fallow is an absolute necessity. (On stock farms the well-mucked root crop, or the green crop folded by sheep usually takes its place.) In view of the evidence already presented in this chapter this is at least suggestive.

In the case of another mechanized farm, this time in East Anglia, the owner a few years ago boasted that there was not a single animal on the place, and that he had been growing heavy crops of wheat and barley continuously, with the help only of large dressings of artificial fertilizers. A year or two after this, the expert who advised him as to his fertilizers, told me himself that the ravages of 'Take-all' in the wheat on this farm had reached such disastrous proportions, that he had advised the ploughing up of all corn land and putting the entire acreage into sugar-beet.

There is no question but that this disease is on the increase; the chemists are trying to find a seed dressing or spray that will stop it, but this is on a par with looking for an anti-toxin for a deficiency disease. Even if it succeeds, you are but curing a symptom. The two examples I have just given are merely straws in the wind, but the evidence is considerably strengthened by an incident that occurred on my own farm. Howard's view is that 'Take-all' in wheat is a deficiency disease, and that the principal primary cause is lack of aeration, this interfering with normal mycorrhizal association. The following personal experience supports this view to a startling degree. I have an eighteen-acre field, which was, for many years, badly in need of draining; in winter it was invariably waterlogged in patches. The soil in question is medium clay loam on a clay subsoil with pockets or drifts of sand in it. In the course of time drains passing through these sand gaults collapse and a kind of pond is formed in the area. There were several of these places in the field varying in size from a few square yards to as much as half an acre and even more. I worked the field for some years before being in a position to drain it, and came to know all these patches well, for whenever the field was sown with winter grain such as wheat, the crop never survived on these patches, which produced only a kind of water grass. The outline of these places was irregular in shape, but well-defined, and year after year, exactly the same outline was invariably visible in the growth of the water-grass, and the absence of the crop. One year, shortly after I had first met Howard, and studied his work, we had an exceedingly dry autumn, winter and spring. The field was under wheat, and as that year there was no waterlogging because there was no rain to speak of, the crop germinated and grew evenly over the whole field. At the flowering stage there was no observable difference between the wheat on the 'wet' places and that on the rest of the field, but by harvest time the wheat growing in the patches normally waterlogged, was all blighted with 'Take-all'. The area of the diseased wheat followed exactly the outlines of the badly drained patches. All the rest of the wheat was perfectly sound. So much for the one time theory that the disease is air-borne.

Now the patches were not waterlogged that year, but by-products of past years of anaerobic conditions were almost certainly still present, and it is safe to say that although the plant roots must have obtained sufficient oxygen in that season, fungal growth, even if inhibitory factors were not present, would not have re-established itself in the time.

Neilson-Jones makes this observation in connection with his investigation of Wareham soil:

'Chief among the initial causes of inhibition of mycelial activity in natural soils is probably low oxygen pressure which depresses fungal activity directly and may do so indirectly from the nature of the byproducts of anaerobic metabolism. Deleterious by-products in the soil may be slow to disappear, even when the causes responsible for their accumulation, such as lack of oxygen, are no longer operating.'

My experience suggests that this applies also to cultivated soils. These are some of the examples of circumstantial evidence which bear on points two, three and four, and I think it must be admitted that they suggest, if no more, that the lessons of the Wareham researches, in connection with soil toxicity, may well be applicable to a much wider field. The evidence concerning the fifth and sixth points on the list can also be considered jointly. These present the question as to whether, in the case of ordinary crop plants, compost acts directly on the roots by supplying plant nutrients, or, as at Wareham, indirectly by stimulating the activity of soil fungi.

On the relationship between fertility and soil fungi in general, Neilson-Jones has this to say

'Study of the causes of soil infertility in Wareham Forest justifies the generalization that in organic soils of the acid type, possibly in all soils, maintenance of the activity of fungi, whether those responsible for the breakdown of organic detritus or those specialized forms concerned in the production of mycorrhizas, is of critical importance. It is not suggested that organisms belonging to other groups are not vitally concerned, but it appears that fungi form an essential link in a mechanism whereby organic detritus is incorporated into humus of a fertile soil and that therefore their activity can be used as an index of fertility; infertility may result either from absence of appropriate fungi or from the presence of factors hindering their activity.'

Lack of aeration is one such factor operating not only directly but also indirectly by favouring the activity of such anaerobic organisms as sulphur-reducing bacteria, which, as mentioned above, can produce H_2S or other volatile sulphur compounds either from sulphates applied to the soil as chemicals, or from organic matter when normal decomposition is arrested. Such activity forms a vicious circle, since the H_2S produced by the bacteria inhibits the activity, among others, of those fungi responsible for the decomposition of organic matter, and the resulting arrest of normal decomposition further encourages the production of H_2S.

One effect of compost is to break this vicious circle, and the enormously increased rate of cellulose decomposition in soil to which compost has been added is one of the proofs of its action through the medium of soil fungi.

In an experiment designed to measure this factor cotton-wool pads of known weight were buried for four months in untreated Wareham soil, in ordinary woodland soil, and in Wareham soil plus C 5 compost. At the end of the period what was left of these pads was dried and reweighed. Representative results based on many repetitions of the experiment showed that in untreated Wareham soil only 10 per cent of this cellulose had been decomposed, in the woodland soil the figure was 33.6 per cent, but in Wareham soil plus compost the percentage of decomposition was over 91 per cent. This experiment indicates a very simple way of testing for fungal activity, and the effects upon it of different soil treatments. It could easily be undertaken on cultivated soils as a regular routine, in conjunction with ordinary field analysis tests for determining soil requirements, and as a measure of fertility. I only know of one place where any attempt to carry out such a test on agricultural land has been made. (See Chapter VIII, also Technical Ref. No. 9.) These tests have not been going on long enough yet for the results to have much significance, but so far the indications are that the highest rate of cellulose decomposition would be found in fields that had received compost, and the lowest in those that had received artificials.

This matter of cellulose breakdown is of vital importance to the whole question of the nutrition of living cells, for it has been shown by experiment that raw cellulose can be as injurious to plants Of great significance also are the changes in resistance to attack by soil fungi that accompany alteration in the soil environment. In Wareham soil a severe attack on the roots of pine seedlings by *M. atrovirens,* here normally innocuous, can be induced by the addition of 5 per cent of pure cellulose to the soil of pot-cultures. In another heath soil of similar type, *Rhizoetonia silvestris* behaves in like manner, producing pseudomycorrhizas encrusted with massive sclerotia on addition of 5 per cent pure cellulose. In both cases the health of the seedlings suffers severely. [Rayner]) as it is indigestible to animals, and in both the soil and the digestive tract of herbivora, cellulose decomposition is largely performed by fungi. (See Chapter VI.)

Such soil treatments, therefore, as ploughing in straw or green crops can only prove successful if conditions for the subsequent breakdown of the cellulose are present. It is useless to apply organic matter in this form while at the same time inhibiting, by the use of certain artificial fertilizers, the fungi capable of converting that organic matter into humus. The increasing use of harvester-combines even on moderately sized farms makes this a question of very particular importance, for the problem of such farms is the disposal of the straw left on the field by the harvesters. Burning is wasteful, and ploughing it in not only presents mechanical difficulties, but is not found particularly satisfactory in its results on the subsequent crop--sometimes definitely the reverse. This adverse factor is not difficult to understand when it is remembered that farms using such implements are usually those on which large quantities of chemical fertilizers are also used, and where nitrogen is given largely in the form of sulphate of ammonia. Sulphates, as we have seen, encourage toxin-producing organisms which inhibit the fungi needed to break down this straw. There are various ways of overcoming the difficulty, one of the most effective being to under-sow the corn with some leguminous crop which is allowed to grow through the scattered straw and then fed off by livestock, but on the stockless farm the 'solution' sometimes adopted is to sweep the straw left by the combine into a heap and to compost it according to the recognized formula of 1 lb. of nitrogen to 100 lb. of dry matter; but the nitrogen generally used for this purpose is sulphate of ammonia! True, this has the effect of breaking down the cellulose and producing a finished product of well-rotted material, not unlike other compost in appearance, but, as the Wareham experiments clearly show, the value of a compost depends upon its organic constituents, and not upon its appearance or its chemical analysis. Failure to recognize this is responsible I think for some of the discrepancy of view regarding the value of compost. The source of the nitrogen used in composting appears to be of considerable importance to the value of the final product. Composts made with chemical activators may increase yield in crops, just as chemicals alone also do--for a time--but the growth of healthy crops showing *maximum disease resistance* has, so far as I can discover, only been obtained when the activating agent is of animal origin. The one exception seems to be in the case of compost the raw materials of which consist of mixed garden refuse including leaves and young weeds in full growth. Such compost can be activated by certain herbal extracts such as those developed by Miss M. E. Bruce with results in the subsequent crops apparently in all respects equal to that of animal activated compost. Such raw materials are, of course, extremely rich in a wide range of trace elements and the resulting compost is rapidly invaded by an immense earthworm population which automatically introduces an animal element. For her work with conifers Rayner found that dried blood produced far better results than any other activator used. The best activating agent for Indore compost for ordinary crops in this country is, in my experience, fresh farmyard manure in which the urine is preserved; this last is very important. I have, however obtained quite satisfactory results by composting with both raw and coagulated blood, and also with sewage sludge, alone and in mixture with muck or blood. The point is that for maximum results in the quality of the crop subsequently grown with it, compost must include some product of animal origin. People who advocate sulphate of ammonia or 'Adco', or other inorganic products for breaking down cellulose in the compost heap, are still suffering from the illusion that humus nourishes the plant direct. The Wareham experiments clearly show that this is not the case. Rayner's findings in this respect were fully endorsed by the independent investigation cited in this chapter.

'That the fundamental effect of the compost is to alter profoundly the soil bionomics is proved by the enormously accelerated rate of cellulose breakdown and the stimulation of the fungus flora in general in soil that has been treated with compost. That the basis for these changes lies in the organic constituents of the compost rather than in the inorganic nutrients it contains is evidenced by the efficacy of leached compost, by the differential effects of composts differing only in respect to organic constitution, by the dissimilar effects wrought by the same composts on different organic soils, and by direct experiment with additions of salts of nitrogen, potash and phosphoric acid equivalent to those contained in a given compost (Rayner, 1939). It is suggestive that the growth-promoting action of compost on fertile garden soils is often negligible or comparatively small; here presumably conditions are already favourable to fungal activity so that additions of compost can do little to improve fertility by modification of the micro-flora.' (Neilson-Jones, *Biological Aspects of Soil Fertility.*)

This supports the view that the effectiveness of compost in cultivated soils depends, just as it does at Wareham, not on its value as a direct plant food, but on its capacity to stimulate the activity of soil fungi. This explains why adherence to fundamental principles in the making of compost heaps is so important, and also why chemical activators fail to produce the degree of disease resistance in plants that result from the use of such composts as those advocated by Rayner and Howard, and also why negative results are reported by users of the putrefactive heaps misnamed compost. Chemical activators will quickly rot vegetable rubbish, but there is much more to the manufacture of humus than this. It involves the creation of what is at once a habitat and a food for soil organisms, but more than this, it must be so fashioned as to favour the activity of the beneficial species and discourage others. There are many species involved besides those responsible for cellulose decomposition, the mycorrhizal fungi forming at least an equally important group.

These various fungi feed on the humus in the soil, and it is the product of their metabolism which is of such vital importance to the complete and balanced nourishment of the plant.

Once this is understood, the necessity for the inclusion of animal, residues in the compost heap at once becomes clear, for fungi require a mixed diet of organic matter. Not only are they unable to take their nourishment exclusively from inorganic chemicals, but they are not even purely vegetarian.

'In 1894, so noted a botanist as Hooker, speaking of the fungi, observed: "these plants seem to invert the order of Nature and to draw their nutriment, in part at least, from the animal kingdom, which it is held to be the function of the vegetable kingdom to sustain."' (M. C. Rayner, *Mycorrhiza.*)

Thus it will be seen, that once you accept the view that soil cannot be fertile when soil fungi are inhibited, then Howard's view on the value of compost and the harm done by many chemical fertilizers and poison sprays, is shown not to be a fad, as some people seem to think, but a perfectly logical conclusion based on practical experience, and supported by scientific evidence.

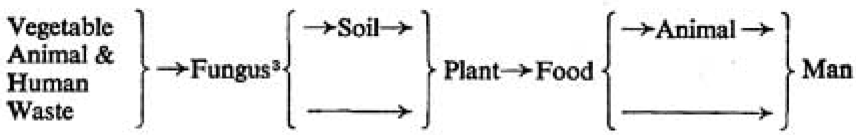
I sum up this chapter with a final quotation from the paper already cited.

'The prescription for compost treatment advocated by Rayner to correct a special case of infertility in a natural soil clearly envisaged removal of unfavourable by-products, with alteration of the soil processes responsible for producing them, in addition to promotion of mycorrhiza formation. The remarkable and persistent improvement in tree growth that followed from this treatment brings the experimental results at Wareham into line with records recently provided describing the action on crop growth of composts manufactured by the Indore process when applied to cultivated soils in many parts of the world (Howard, 1940). The great emphasis laid by Howard on the significance of mycorrhizal activity is a welcome and long-overdue recognition from the practical side of the important part played by this habit in crop nutrition; the indifference displayed to this aspect of soil research by soil specialists is difficult to understand. But the mycorrhizal habit, although widespread is not universal in vascular plants; the soil possesses fertility in its own right as reflected in the growth of non-mycorrhizal as well as mycorrhizal plants. *It is the free action of fungi that is regarded as essential for the development of soil fertility;* (Italics mind (author.) that some of the species concerned also form mycorrhizal associations with certain of the higher plants may be to the advantage of the latter, but this is additional to and different from the generalized service that fungi, mycorrhizal or not, perform in the soil--it provides an alternative channel uniting mycelial activity in the soil with the nutritive processes in vascular plants.

'The analyses of a particular case recorded in the present researches shows very clearly some of the ways in which a condition of biological inertia in the soil, however produced, may bring about infertility for growth of the higher plants, and has yielded direct evidence of some of the ways by which additions of organic material operate in restoring fertility.

'It is realized that there are gaps in the argument as presented in this paper; it could hardly be otherwise in view of the complexities involved. Nevertheless, the evidence is so striking that disturbance of microbiological equilibrium in the soil by inhibition of fungal activity is a potent factor in bringing about infertility for growth of vascular plants, its direct relation with the results of forestry researches so impressive and the possibilities of wider application so evident, that publication at the present stage of the work appeared to be justified.' (Neilson-Jones, *Biological Aspects of Soil Fertility,* Cambridge University Press, now published as part of *Problems in Tree Nutrition,* Rayner and Neilson-Jones, Faber and Faber.)

It seems that the equation in the Medical Testament should be redrawn thus:



3 The word Fungus is here used to denote various groups of fungi in association with other micro-organisms.

CHAPTER VI
INDICATIONS

'The test of a diet is the wholeness of those who eat it,'
G. T. Wrench, M.D.

I
PLANTS

In the last two chapters I sought to explain the complex character of compost action, and to show that humus in the soil benefits the plants in three ways: mechanically, as a direct plant food, and by fundamentally modifying the soil bionomics. Of the three, this last, hitherto largely ignored, is probably the most important.

I have shown that the action of soil fungi plays a vital part in the nutrition of certain plant species, and have given evidence of strong indications that the health of all plants growing in soil is affected to a greater or less degree by the activity of the soil micro-flora in general, and that it is the natural habit of the great majority of our crop plants also to form direct association--probably symbiotic--with specific soil fungi. Keeping this aspect of plant nutrition in mind, we are now in a position to consider the value of further evidence bearing on the relationship between soil fertility and health.

In Chapter I, I gave a summary of the far-reaching claims made by many advocates of humus farming. Let me remind you what these are. That if the fertility of the soil is built up with adequate supplies of humus, crops do not suffer from diseases and do not require poison sprays to control parasites; that animals fed on these plants develop a high degree of disease resistance, and that man, nurtured with such plants and animals can reach a standard of health, and a power of resisting disease and infection, from whatever cause, greatly in advance of anything ordinarily found in this country.

Some mention of the evidence on which these claims are based has already been made. It is now time to consider a wider field of such indications as exist in support of them.

Let us take plants first. The claim speaks of resistance to disease and parasites. We must consider the evidence under these two categories separately.

By plant disease, is usually meant those ailments which are caused by virus, bacteria, or special parasitic fungi. It is well known that a shortage of certain essential soil ingredients, besides causing derangement in the plant's metabolism, can also induce some of these disorders; in fact in some cases the particular soil deficiency can safely be deduced from the appearance in a crop of the disease in question. As an example, 'finger and toe' in turnips indicates a lack of lime in the soil, and very many diseases are now explained by lack of some essential trace element. Deficiency diseases, in other words, are not confined to the animal kingdom.

This being so, it does not require a great feat of credulity to accept the view that *if* any aspect of normal plant nutrition depends on fungal activity, then the disease resisting capacity of any plant will be weakened by removal of this element from its diet. Particularly should we expect to find such lowered resistance resulting from inhibition of mycorrhiza) fungal activity in those plant species which normally form mycorrhiza) associations. Yet the condition of mycorrhiza) activity is seldom taken into account by plant pathologists.

'No true picture of the soil as an environment in which the root system of vascular plants passes its life can be formed if there is omitted a biological component so frequently present and often so abundantly developed as the mycorrhiza) system. For example, although there may be at present no information as to the interaction of this habit with the organisms, and soil factors, operative in root diseases, yet it would appear dangerous to assume none to exist. Nevertheless, instances are not wanting in recent researches in which the normal condition of the root tissues in respect to mycorrhiza) infection, even in well-known and admitted mycorrhiza formers, is completely ignored in pathological investigations.' (Rayner, *Empire Cotton Growing Review.*)

In cases of disease due to parasitic fungi, there are good grounds for believing that the power of the host plant to resist attack may be closely bound up with mycorrhiza) association. In discussing this point with regard to pines, Rayner states

'Study of these soil inoculation experiments raises a matter of practical importance in relation to mycorrhiza) associations in general. It is already clear that the damage inflicted by soil fungi such as the forms of *M. r. atrovirens* and *"Rhizoctonia"* now under discussion does not depend merely upon the propinquity of mycelium to the roots. Apart from direct effects of the soil environment it is conditioned by other factors such as the vigour of the root system as a whole, the presence of suitable mycorrhiza formers, and the capacity of the host for mycorrhizal association. In cases where root response is satisfactory in these respects, there appears to be more or less complete immunity from parasitic invasion.'

Elsewhere she writes:

'Discussing this matter in reference to certain plant diseases, especially those of sugar-cane, it has been pointed out recently that disturbance of the normal activity of the mycorrhiza) fungus may lead to secondary invasion of roots by bacteria or parasitic fungi, e.g. species of *Marasmius* or *Rhizoctonia* (Constantin, 1924).'

My own experience recorded in the last chapter, concerning 'Take-all' in wheat on the badly drained field, is very probably a case of this kind. The interaction, if any, of the mycorrhiza) fungus with the activity of the fungus responsible for 'Take-all' has not, so far as I know, been studied, but since wheat is a mycorrhiza former it is more than likely that some such connection exists.

In fact, once accept as a likely hypothesis that under normal conditions plants derive some part of their food (something possibly analogous to vitamins), from substances resulting from the activity of certain soil fungi (and in view of the evidence it is difficult not to accede so much), then the recorded cases of plant disease being cured or prevented by compost treatment are readily explicable. That many such cases do exist is incontestable. Examples have already been given in respect to tea, cotton, grapes, sugar-cane, and strawberry. This year Howard records the following further experience with strawberries:

'I grew in heavily composted soil a collection of Royal Sovereign strawberries, badly infected with a common virus disease, alongside some healthy stock. This year, 1942, the strawberries raised from these two sets of plants were about the best I have ever tasted. I found no trace of the virus disease. Similar results have been obtained by several of my correspondents.'

Results of the use of compost are in fact now available from all over the world. Here are a few representative examples. Mr. R. Paton of the Morib Plantations Ltd. of Banting in the Federated Malay States, writes:

'We started to keep livestock on a fairly big scale in 1930 for the purpose of manuring our coconuts, and this was done in conjunction with composting of husks, fronds, etc. in trenches two feet deep along the centre of each row. . . . Our average yield per acre was below nine piculs of copra, and the palms were then beyond the age at which one would expect any appreciable response in yield. Nevertheless, they have yielded over fourteen piculs per acre average for each of the past five years, and look like doing even better. Fine results have been obtained also in our rubber areas, particularly in young replantings, where the growth is all that could be desired, and not one ounce of artificial fertilizer has been used.' (*Compost News Letter No. 1.* A four-monthly periodical published by the County Palatine of Chester Local Medical and Panel Committee. Later incorporated into *Soil and Health.*)

A good example from Europe was to be seen before the war on Dr. Pfeiffer's farm, near Flushing in Holland. Neither his green-house nor his outdoor crops received any artificial fertilizers. He succeeded in producing heavy crops of a flavour and keeping quality far in excess of those in the surrounding neighbourhood. Moreover, he never needed to use poison sprays because he was not troubled with insect or fungus diseases. Dr. Pfeiffer follows the bio-dynamic method of agriculture advocated by the late Dr. Rudolf Steiner. It includes the production of high quality compost, fortified by various herbal and other organic preparations. E. Pfeiffer, *Byo-Dynamic Farming and Gardening,* published in the U.K. as *Soil Fertility, Renewal and Preservation,* Faber and Faber, 1947.) Dr. Pfeiffer is now engaged in important research work in the United States of America.

Africa has provided many indications in recent years. In a foreword which Lord Bledisloe contributed to the pamphlet on this subject (referred to in Chapter IV) he records 'the amazing justification' of the Indore process of humus manufacture which met his eye 'in every direction' when he visited south Central Africa in 1938 as Chairman of the Rhodesian Nyasaland Royal Commission. 'There I found,' he says, 'on the one hand, vast areas of desiccated and exhausted land, utterly destitute of humus, which provided sustenance for neither man nor beast and where disease was rampant among the native tribes, and on the other hand, in striking contrast, bumper crops of tea, coffee, cotton, tobacco and maize being harvested by natives who were relatively healthy, the secret being the use of compost, made (generally by the Indore system) out of decayed vegetation associated with animal and human residues.

'The fact that the discoveries of McCarrison indicated that immunity from degenerative human disease followed the ingestion of a fresh, well-balanced diet of unprocessed natural foods, and that those of Howard disclosed a marked similar resistance capacity, to both degenerative and infectious maladies, as a consequence of returning to the soil a sufficiency of carefully prepared waste products may be regarded as something other than a coincidence. In the latter case both crops and livestock showed this salutary immunity.'

From Rhodesia Captain Timson reports 'that the resistance of maize to the attack of witchweed, a flowering semi-parasitic plant, was raised to a point approaching immunity by manuring with Indore compost.' (Howard, Letter to *The Times,* 10th August 1939.)

This result was confirmed by Captain Moubray of Chipoli who also records (1942) that in an exceptionally dry season (only two inches of rain fell between the end of January and middle of March) the pollen on the maize 'just dried up' nevertheless 'lands throughout the colony that were well composted stood up well and gave good results. The government', he states, 'are now appealing to everyone to make as much compost as possible.' Another 'outstanding fact' has been the seed production from composted sunn hemp as compared with that where no compost had been added. This seed crop he reports as being very bad throughout the colony, the average yield being only about one bag per acre, but 'notwithstanding bad rain conditions' his own composted crop yielded three bags an acre. He gives it as his considered opinion that it is not really profitable to grow sunn hemp for seed without the addition of compost. (*Compost News Letter No. 4.*)

Coming nearer home, the effect of organic manuring on quality in vegetable growing can be seen on a large scale on Mr. Secrett's farm at Walton-on-Thames. 'Mr. Secrett uses practically no artificials and raises his produce on fermented stable manure. He stands at the head of his profession as regards quality.' (Howard.)

Lord Portsmouth has made an interesting contribution to this question in connection with keeping quality. Wheat straw is used for thatching many of the cottages on his Hampshire estate. By keeping careful records over a number of years he found that, although the crops in question were grown side by side on the same type of soil, thatch made with straw from wheat grown with humus lasted twice as long as that grown with artificials.

One of the most impressive examples of large scale humus farming in this country is to be found at Surfleet near Spalding in Lincolnshire, on the Iceni Estate, owned and farmed by Captain R. G. M. Wilson. This particular farm, consisting of nearly 300 acres, is of special interest because of the interdependence of its market garden, and more normal farming departments, but in connection with the special subject matter of this chapter, I am concerned with a result which he has noted in connection with the use of compost (Made on the bio-dynamic principle.) on glass-house tomatoes. This case is of interest because it is an example of the beneficent effect of compost on a presumed non-mycorrhiza former. When he first started growing tomatoes on a large scale, Captain Wilson tells me he was much troubled by that uneven ripening of the fruit which is such a frequent cause of loss to commercial growers of this crop. He first tried the treatments advocated by expert consultants without any very marked success. Then he adopted his humus methods and this trouble disappeared; moreover he has now grown a crop of tomatoes in his houses for eight consecutive years without changing or sterilizing the soil and, so far, can detect no falling off in yield or quality. This is usually considered by experts to be impossible. (This result has been confirmed by several other commercial tomato growers. Again and again they have reported the complete disease control by the use of compost only. Incidentally, the tomato is one of the plants that thrives best on compost made from its own waste materials.)

The high quality of the Iceni produce is famous wherever it is known, and Captain Wilson has demonstrated very clearly that quality, even to-day, has a very definite commercial value. This is often contested by the users of chemical fertilizers who argue that successful competition under modem marketing conditions involves putting quantity before quality. Recently during one of the periodical bad slumps in the demand for cabbages, brought about by a seasonal glut of that vegetable, Captain Wilson sent a van load of cabbages to the market of a town in the Midlands. When the name on his van was spotted, it was quickly surrounded by buyers, and the whole load was easily disposed of. Afterwards, rather than return empty, the van loaded up with the unsaleable cabbages sent, on the same day to the same market, by other growers. These were taken back to Surfleet and added to the compost heaps.

Plant pathologists when visiting Surfleet have jokingly called it 'a most uninteresting place', because it is, as they put it, 'so boringly healthy'. If the primary cause of disease in plants (as in man) is faulty nutrition, then Captain Wilson can claim that his organic treatment supplies his crops with a balanced diet.

We must now turn to the question of parasites proper. These can be divided into those that live in the soil and attack the roots or stems of plants, and those (such as insects) that live outside the soil, and usually attack the leaf structure.

We have seen that the beneficial effect of compost in controlling virus or fungus disease is probably due to increased fungal activity, and the part this plays in providing the plant with a balanced diet. I now hope to show that there exists an equally plausible reason to explain the decrease in attack by parasitic grubs, which so often follows humus treatment. One of the most interesting examples of the kind is the effect on eelworm which has recently been noticed in South Africa and Ceylon following applications of compost. An account of this appeared in the *Rhodesia Herald* of 4th September 1942 as follows:

'Some years ago Mr. S. D. Timson, Assistant Agriculturist, noticed a garden in which the vegetables were strong and healthy and the flowers bright and vigorous. He was surprised to learn that three years earlier cultivation had been almost abandoned because of the heavy infestation of eelworm. The excellent conditions he saw followed a good dressing of compost.

'He immediately began to observe the results of compost in regard to eelworm, make practical tests and induce farmers to experiment. Once the inquiry was begun evidence began to pour in.

'At Darwendale Mr. O. C. Rawson had applied five tons of compost per acre to infested tobacco land. In the first year there was a reduction of eelworm, and in the second year, without a further application, the eelworm disappeared. Other tobacco farmers began to report similar experiences. . . . The compost, of course, was applied for its fertilizing value and the consequences on the eelworm population were a surprise.

'It now seems that the same effect has been noticed in other countries where compost was being tested out. In Ceylon members of the Department of Agriculture were able to report last year that the most promising method of ridding the soil of eelworms was one they had only recently discovered. It had been found that if large quantities of organic material, such as compost, green manure, or cattle manure, were added to the soil the population of eelworms was greatly reduced. Examining into the causes of this effect, their conclusion was that it was due to the increase in the soil, following the addition of organic matter, of organisms like fungi, and insects, and other nematodes, which preyed on the eelworms. . . .'

This result would not have been a surprise if the machinery for coordinating the results of research in different branches of science were less rusty. No less than fifty-six different species or forms of fungi have been recorded by mycologists as 'subsisting by the capture of motile animals'. (Charles Drechsler, 'Predacious Fungi', *Biological Review,* Vol. 16, 1941, pp. 278 and 290.) The first account of this phenomenon appeared as early as 1888 (Zopf). Of these fifty-six forms, twenty-five are known to capture and consume nematodes, twenty-three kill and eat amoebae, five live upon rhizopods and the three remaining species are aquatic.

The methods by which these fungi trap their prey vary. The majority of the nematode-eating species form loops or bales of mycelium, which also usually excrete an adhesive substance. When an eelworm crawls through these bales, they close round it, holding it captive despite its violent struggles which may last for as long as two and a half hours. When the captive becomes inert, the fungus bores through the skin of its prey, making a narrow penetration. A globous body is then formed by the penetrating mycelium, which increases in size until in an hour or two it has filled a transverse section through the animal's body. Lateral elongated branches then grow from this, passing between the captive's internal organs, until they fill its entire length. This causes paralysis and death of the eelworm, after which the fungus consumes all the internal fatty material of its body, leaving the cuticle untouched. This gruesome process is well shown in Plate XI.

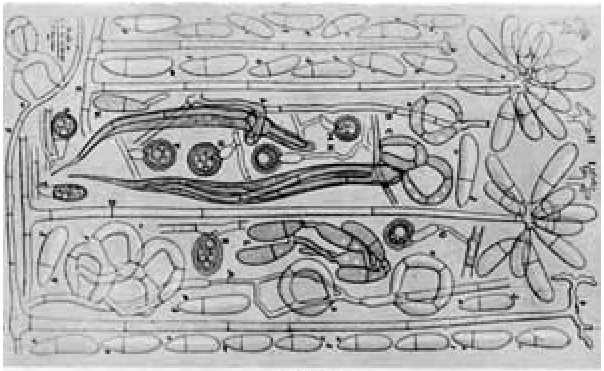


Fig. 1

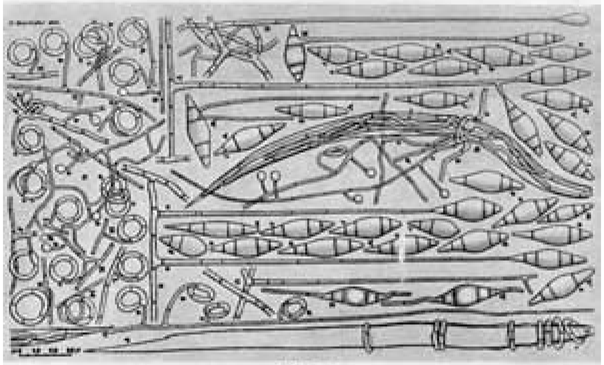


Fig. 2

PLATE XI. *Arthtobotrys musiformis* (*Fig.* 1) and *Dactylella lysipaga* (*Fig.* 2) Two species of predaceous fungi, showing method of capture and destruction of eelworms. From drawings by C. Drechsler. *Mycologia* 29 447 1939.

Nematodes appear to form the normal diet of some forms of predacious fungi, other forms, it seems, eat such active prey only in the absence of other food. Comparatively recent investigations have disclosed the fact that many more forms of fungi are predacious than has been supposed. These forms have all the appearance of non-predacious species until brought into close proximity with their mobile prey. Then, and only then, do they develop the catching apparatus.

Many forms of these fungi are normally found in rotting vegetable matter and the dung of animals. An examination has also revealed their presence in very large numbers in compost.

Besides capturing and eating the active larvae of nematodes parasitic to plants--such as wheat cockle and sugar beet eelworm, and the rootknot parasite of pineapple--some forms also capture and consume the larvae of many animal parasites. These larvae, which are present in the dung of affected animals, are quickly snared and killed by the fungal species concerned. (See Technical Ref. No. 7a.)

This probably explains the greater liability to attack by parasitic worms to which cattle and sheep are subject on worn out pastures deficient in humus, for it is unlikely that predacious fungi can thrive in the absence of humus, any more than other soil forms.

Whether or not these groups of fungi are among those concerned with the production of growth-promoting substances is not known. It would be rash, in the absence of precise knowledge, to assume that they are not. If they *are,* then the deliberate destruction of eelworms by chemical means, may, even where successful, do more harm than good by destroying the natural food of these beneficial fungi. The normal presence in dung of both nematodes and the fungi which eat them, certainly suggests that a balance between them exists in nature, particularly as some nematodes and rhizopods appear also to eat fungi, if not first eaten by them. These organisms provide an instance of the importance of the study of soil ecology, and of the possible evil consequences of upsetting nature's balance of species.

'"There is no human being who is not directly or indirectly influenced by animal populations, although intricate chains of connection often obscure the fact . . . not only do animals have this influence on man, but man has an increasing power over the fate of the animal populations that still throng the world." It seems that considerable caution should be exercised before "ordering the destruction of a species on the chance that it may be doing harm to human interests." (Bureau of Animal Population at the University of Oxford--Annual report, 1936-37, quoted from *The Rape of the Earth.*)

'We cannot condemn the prairie gopher, the Australian rabbit, the African termite, or the locust, without first discovering to what extent, if any, some action of man has upset an equilibrium in animal ecology, and therefore indirectly in plant ecology, and so affected the conservation of vegetation, soil and water.' (Jacks and Whyte, *The Rape of the Earth,* Faber and Faber, 1939.)

Man is certainly responsible for the devastations caused by the Australian rabbit, though in this case he upset nature's balance by the introduction, not the extermination, of a species. As for the African termite, Captain Moubray has recently shown that it can serve a very useful purpose. He uses large quantities of compost on his citrus farm in Rhodesia, and he has described (April 1942) how he has recently been able to make use of the termite in providing an additional source of food for his trees.

'We have a small box-making plant,' he writes, (*Compost News Letter No. 4.*) 'and until recently sawdust was looked upon as a waste product. Now it is spread on the grove, where the termite or white ant of the insidious variety has made its home. This insect has the property of fixing atmospheric nitrogen, which enables it to digest cellulose and convert it into protein, which is a valuable source of nitrogen.

'We used to look upon the insidious termite as a pest and sawdust as waste. By combining the two we make a valuable product. The termites do no harm to the trees. The American representative of Cyanogas pays me regular visits, and has been watching this particular experiment with great interest.'

In a later letter Captain Mowbray writes: *'Re* termites, I now think the correct explanation is as follows; the termites take the sawdust underground and use it in the manufacture of their mushroom beds; this particular termite makes nets about the size of a cricket ball, only a few inches below the surface. When finished with, these beds decompose, nitrification takes place, and the nitrogen is available to the roots of the orange trees. As regards eelworm in tobacco, our experts appear to be fairly satisfied that this pest is now controlled by good applications of compost. Up till recently it was generally accepted that once lands became badly infested they were lost to tobacco forever. Many more have repeated Mr. Rawson's and Captain Timson's trials with the same results. I found this out on tobacco years ago, but people then treated it as a joke.' (Note: the expert advisers on sugar beet and potato eelworm in this country still treat it as a joke.)

Whenever pests appear in unmanageable numbers, it is probably safe to assume that nature's balance of species has in some way been upset, and in most cases it would be profitable to suspect that the root of the trouble is man's mismanagement. For example, there is some evidence for attributing the increase in insect pests, which has been reported in some areas, to the wholesale destruction of hedges, undertaken in the interests of mechanized farming, for with the hedge has gone the shelter for the small birds who prey on the insects. Similarly, any soil treatments which tend to inhibit fungal activity are probably a direct or indirect cause of the increase in many different forms of parasitic larvae. In Hawaii successful control of root-knot parasite in pineapple has been achieved by treating the soil with large quantities of organic matter applied with the deliberate intention of encouraging predaceous fungi. (See Technical Ref. No. 7B.) Farmers on the eelworm-infested potato lands in Lincolnshire might do well to follow this example.

In addition to the undoubted presence of predaceous fungi in such substances as compost and dung, other factors concerned with the balance of the soil population are probably called into play as a result of organic soil treatment. There are indications, for example, that attacks by wire worm on newly ploughed up pasture are noticeably less severe if the grass receives a heavy dressing of farmyard manure before ploughing.

PLATE XII A pair of Meyer lemons showing greater all-round development of the plant on the right which was implanted with Soilution earthworms eighteen months previously.

(Reproduced by courtesy of the Director, Californian Earthworm Farms)

Not the least important effect of replacing chemical fertilizers by farmyard manure or compost, is the increase which this brings about in the earthworm population. Darwin found that the weight of worm casts deposited on the surface of ordinary field soil in good heart may exceed ten tons per acre per year. The importance of this (see Plate XII) and its direct bearing on plant nutrition, becomes clear when you consider the estimates of other experts, notably Dr. L. C. Curtis of the Connecticut Experimental Station, that worm casts contain five times more nitrogen, seven times more available phosphate, eleven times more potash, and 40 per cent more humus than is normally to be found in the top six inches of soil, and this is not their only contribution to soil fertility.(A list of some of the further beneficial activities of earthworms will be found in Technical Ref. No. 8.) The late Sir Bernard Greenwell attached great importance to the part played by earthworms in pest control and in the production of healthy crops generally. In a paper which he read to the Farmers' Club in 1939 he stated:

'I am afraid very few of us realize what a good friend this little fellow is to the farmer, and if we can only increase the population of the earthworm in the soil he will do a lot of our deep cultivation for us and aerate the soil gratis. Where we manured our grassland with artificials, we found the worms disappeared, but the following year a compost was applied made from town rubbish mixed with dung, and immediately the worm casts reappeared. It is a known fact that the nomad tribes in Central Africa always pitched their camp on ground covered with worm casts as they found that this was the best grazing. . . . I am certain that the fertility of the soil is bound up with organics which are a great encouragement to the worm. There is very little doubt that he is a scavenger and if he disappears you will find his place taken by the leather jackets and other insects detrimental to the crops.' (It has also been suggested (Dr. Joad, in a Brains Trust session) that the increase in such pests as wireworm, and leatherjacket, may be attributable to the speed of the multifurrow tractor plough, which does not allow the grub eating birds sufficient time to secure their prey before the fresh-turned soil is covered up again by the next furrow. This is very plausible, and there is probably something in it.)

When it is remembered that as many as eight million earthworms may be found in a single acre, and that their burrows are capable of penetrating the subsoil to a depth of five or six feet, it is clear that their presence must have an appreciable effect on soil aeration, and thus indirectly on humus formation.(See Technical Ref. No. 8.) Faulty aeration, which interferes with humus formation underneath the turf, is perhaps the commonest cause of infertile grassland.

Sir Bernard Greenwell found that he could obtain an improvement in poor pasture by subsoiling, equivalent to that normally obtained by dressings of basic slag. It will be remembered that some of the Wareham experiments suggested that the improvement in tree growth brought about by slag was due less to its phosphate content than to its indirect action on soil fungi, including no doubt those responsible for humus formation. It seems fairly clear that an increase, however induced, in that part of the soil population beneficial to plant life may well be accompanied by a decrease in others of a parasitic nature.

We come now to consideration of the claim that compost treatment also confers a resistance to attack by *insect* parasites. Here the reason is more difficult to understand. At first sight one would have thought that the healthier a plant, the more appetizing would it be to such pests. The recorded cases of such resistance following applications of compost, are however too numerous to ignore. My own experience extending over several seasons has convinced me that crops of the cabbage family, if grown from seedlings raised on humus rich soil, and transplanted on to land treated with compost, show markedly greater resistance to caterpillar and aphis attack than those grown with artificials or even with ordinary farmyard manure. (See Chapter VIII.) I have also grown onions in soil rich in humus which produced an abundantly healthy crop in a season when practically the whole onion crop of the surrounding district was destroyed by onion fly.

Howard records the following interesting experience with fruit trees found growing in the garden of his house at Blackheath when he bought it in 1934. He records that this garden 'was completely worn out through no fault of the previous owner. It was a veritable pathological museum--the fruit trees, in particular, were smothered with every kind of blight. Steps were taken to convert all the vegetable wastes into humus with the help of stable litter. Even after one year the pests began to retreat. In three years all had disappeared, the woolly aphis on one apple tree being the last to leave. During this period no insecticides or fungicides were used and no diseased material was ever destroyed. It was all converted into humus.'

Every year that passes brings an ever increasing number of carefully recorded results of a like nature, for organic farming and gardening is daily becoming more common. Among the outstanding features of all these reports are the disappearance of disease, the increased size, and improved germination of seed, and the increased resistance to drought and pests, all following upon a change from orthodox cultivation to compost only. In none of these cases has a diminution in yield resulted--usually the reverse. (These results are now being collected and checked by the Soil Association. See Chapter VIII.)

I have evolved my own theory to explain the effect of compost on insect pests, which I advance here merely as an hypothesis. In watching caterpillar and aphis attack I have noticed that both compost- and chemically-grown plants will be attacked, but whereas the plants grown with chemicals (if left unprotected) will, in a bad season, be stripped to the rib, those grown with compost (with the exception of an occasional isolated plant) are only slightly damaged and quickly recover. This suggests two things: first, that the vigour of growth is so strong in the case of the compost-grown plants, that they are able quickly to repair the ravages of the pest, and secondly, that the compost grown plant may be more nourishing and the parasite consequently satisfied with less. The evidence on which I base this theory will be found in the next section.

II
ANIMALS

We now come to the second claim made on behalf of humus, namely that the health of the crops grown with it can be transmitted to animals. This is not easy to prove, but as an example of the instances given, I will briefly summarize the experience of Mr. Friend Sykes, farmer of a 700 acre all-organic farm. For many years Mr. Sykes farmed some of the richest land in the country, where he built up famous prize-winning herds of Friesian cattle and Berkshire pigs, yet when the accredited milk scheme was introduced, and he was asked to lead the way by having his herd tested for tuberculosis, 66 per cent of his cows reacted. As can be imagined this caused him many heart searchings. For the conclusions he reached, and the reasoning by which he arrived at them, readers must study his book, (Friend Sykes, *Humus and the Farmer,* Faber and Faber, 1946.) but the practical upshot of them was that he decided radically to alter his system of farming, and abandon orthodox methods. He sold his rich land farm (at £100 per acre) and in 1936 bought 750 acres of downland in Wiltshire over 800 feet above sea level and worth only £4 an acre.

This land was so poor that it was said to be incapable of growing grain crops, and the herbage was so scant that the whole area, when he first moved in, was incapable of sustaining fifty head of cattle, and heavy purchases of feeding stuffs had to be made to keep them alive. Disease of every sort soon showed itself: contagious abortion, Johne's disease, mastitis, tuberculosis.

He decided to plough up the whole 750 acres, to rely thereafter solely on home grown food, and to attempt to re-establish fertility without recourse to any purchased artificial fertilizers. He records the result in the following words: 'After seven years of heart-breaking toil with the added difficulties of wartime conditions thrown in for luck, we have (touching wood) (1) almost completely rid the farm of disease, (2) built up a large herd of attested dairy cattle tubercle free for over four years now, and of a soundness of constitution to all critical appearances such that no expert would believe that any scourge had ever visited the farm, and (3) as each succeeding generation of young stock is born we have unmistakable evidence of still greater stamina and endurance.'

This remarkable achievement was brought about by a combination of ley farming (four years seeds, four years arable), heavy cultivation including sub-soiling, and intensive controlled grazing by cattle, sheep and horses. Beyond this heavy sheet composting the land received nothing, yet the farm, once so poor, is now self-supporting, carries 250 head of cattle, and grows heavy crops of roots and grain, which are as healthy as the livestock. In 1944 the wheat crop reached seventy-two bushels per acre, and this on land said to be unsuitable for wheat both on account of quality and altitude.

The farm is still on the up grade, and now that Mr. Sykes is composting all his straw by the method of open yards and a mechanical muck shifter he expects to be able to carry a much larger head of livestock still.

Now this conversion of derelict and infertile soil into something much above the average for the best, through no agency other than the dung and urine of the livestock *fed on the farm's own produce,* while grain and milk are sold off the farm, cuts clean across the orthodox view of what is possible. By all the rules a serious mineral deficiency should have taken place. The reverse appears to have happened.

If animals fed on compost grown food *are* healthier than those fed on the same foods grown by other means the explanation is probably to be found in a combination of many factors, and to single out any one of them is perhaps to fall into the error of fragmentation. Nevertheless since vitamins have already been singled out for special investigation in recent research on this subject, and since they undoubtedly do appear to be one of the factors concerned, some of the available evidence in connection with them must now be given.

In Madras McCarrison found that grain produced with farmyard manure contained more vitamins than that grown with minerals. In the *Journal of Medical Research,* Vol. XIV (1926), p. 351, the following results of one of his rat feeding experiments demonstrates this:

Feeding	*Percentage gain in bodily weight*
Basic ration plus stable-manured wheat	114
Basic ration plus chemically grown wheat plus vitamin supplement	104
Basic ration plus chemically grown wheat alone	89

The two wheat crops were grown on adjoining plots. (*Memoirs of the Department of Agriculture in India,* IX, No. 4, 8927. Quoted. Pfeiffer.)

A striking confirmation of this finding in the case of a particular vitamin--'B--'is to be found in an experiment carried out by Rowlands and Wilkinson of the Knightsbridge Laboratories.

The following account of their experiment appeared in *Compost News Letter No. 4* and was abstracted from the *Biochemical Journal,* Vol. XXIV, No. 1, 1930.

'Mr. Rowlands, having noticed that pigs grown on home-grown barley and wheat did better than pigs on bought barley and wheat, decided to try the effect of artificial manure versus natural manure. The crop tested was, not barley or wheat, but the seeds of clover and grass; and the experimental animals were rats. Two groups of rats were fed respectively on the seeds from the artificially manured field and the naturally manured field; and the upshot was that, on the seeds of the naturally manured grass, the rats grew nearly twice as well as those on the artificially manured grass. Both preventive and curative tests were made.

'Here are the details:

Preparation of field	1925	Cabbages grown.
	1926	Potatoes grown. Wheat sown in autumn.
	1927	Grass seeds with a small quantity of the different clovers sown amongst the growing wheat. After harvest, the aftermath was lightly grazed.
	1928	Field cut for hay and grass. In autumn the field was divided and half was manured with natural manure and half with artificial thus:

Natural	*Artificial--*
Pig manure mixed with straw 20 loads per acre.	20 cwt. basic slag and 3 cwt. Kainite (sulphate of potash,
.	
How the pigs which produced the manure were fed	salt and magnesia) per acre
50 per cent middlings (i.e. ground bran with adherent endosperm)	
40 per cent barley meal	
10 per cent of the following mixture: meat meal, rye and wheat embryo (rich in vitamin B),bone meal and cod liver oil	1929 In the spring 1 cwt. sulphate of ammonia per acre.

Harvest

'In July 1929 the crops were cut on both parts of the field; harvested in separate barns, and threshed.

Analysis of Grass and Clover Seeds (percentages)

	After natural manure	*After artificial manure*
Protein	12.7	11.7
Moisture	5.8	6.0
Fibre	19.4	21.6
Ash	9.0	10.5
Phosphorus	0.44	0.33

Preventive Tests

'The rats were given Professor Drummond's "B deficiency diet" which consists of rice starch, caseinigen, salt mixture and cod liver oil, and with this, one lot got 20 per cent of "Dung Seeds" (seeds grown with natural manure) for twenty-one days and thereafter 25 per cent of "Dung Seeds" for eleven days, whilst the other lot got the same weights of seeds grown with "artificials", for the same periods. The result is shown in Fig. 2.

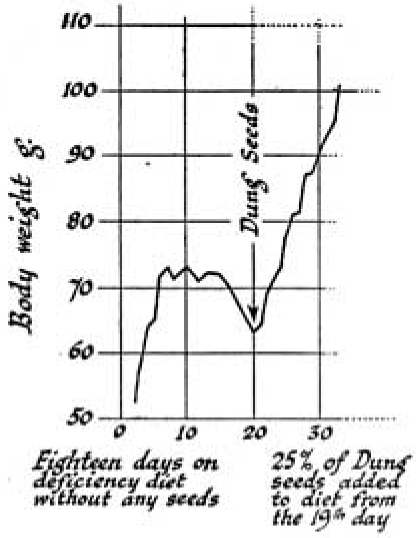


FIGURE 2

Curative Tests

'Both lots of rats to be tested were given the "B deficiency diet", with no seeds, for eighteen days, at the end of which all were losing weight. Then to the diet of one lot 25 per cent of "Dung Seeds" were added, and they at once began to grow normally. (See Fig. 3.)

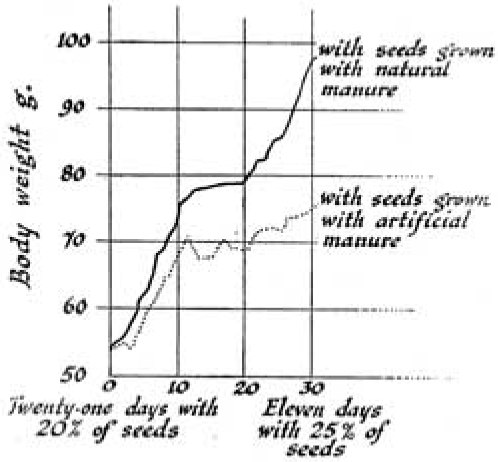


FIGURE 3

'To the diet of the other lot 25 per cent of seeds grown with "artificials" were added: they did not improve, but got steadily worse. Three days later they looked as if they could only live a few hours. "Their condition was one of typical vitamin B deficiency; they were wasted, hunched and shedding hair". Then Professor Drummond saw them and suggested changing from seeds grown with "artificials" to "dung seeds". The immediate result was that the rats rapidly recovered and showed normal growth. (See Fig. 4.)

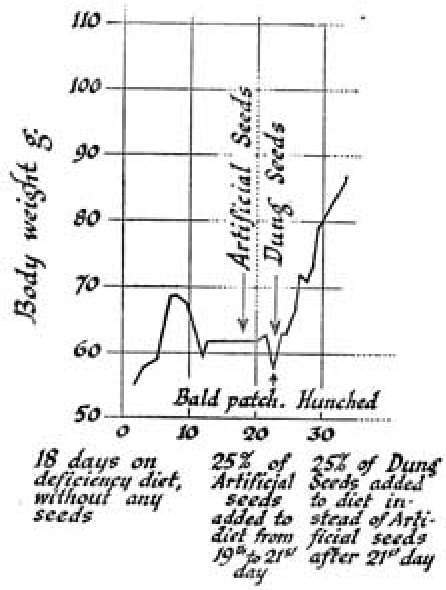


FIGURE 4

'The authors observe "It would seem that a plant may absorb vitamin B from the land, and that the vitamin B content of any food may be dependent upon the amount of this vitamin in the land." The earlier view that "the vitamin B is manufactured entirely in the plant and stored in the embryo" thus seems to be incorrect. Then they make this shrewd remark: "One worker states that in his experimental work a certain food contains vitamin B ; another worker, using the same type of food, differs entirely in his findings; and we consider that the food that is being tested is not the only point which is of importance. If these results are correct they have a considerable bearing upon agriculture and nutrition."

'A further detail: They found that the dung of the pigs which they employed contained vitamin B. (They extracted it with slightly acidified 50 per cent alcohol, concentrated the extract by distillation in vacuo, and then fed the concentrate to rats losing weight on the "B deficiency diet". The rats began to grow at once.)'

This experiment dealt with vitamin B only. Very probably it could be extended to include others. A similar result, but without an attempt to isolate the cause, is recorded of the late Dr. Rowlands

'In his case he took an acre of land that had never had a crop on it, divided it into two half-acre plots, ploughed, harrowed it, and made a seed-bed of the whole acre. One half-acre was heavily fertilized with cow dung, the other half-acre with chemical fertilizer--both plots seeded down with the same cereal--barley I think it was--both plots had good crops with strong straw and well-filled heads, the seeds were kept separate and again two groups of rats from the same families were divided in equal halves--the one group fed from the chemically fertilized plot showed every evidence of malnutrition--those fed from the farmyard manured plot had a perfectly normal healthy growth.' (Personal letter to the author from Mr. J. Tustin, late of United Dairies.)

As against such experiments as these I must in fairness record certain contrary evidence. First there is the increasing development of soilless culture, or hydroponics as I believe it is called in the U.S.A. It is usually described as growing crops in a nutrient solution, either in water tanks or in sterilized sand or gravel, though it is sometimes forgotten that water or sand when exposed to the air does not remain sterile. Considerable progress has been made in this method. It has even reached a commercial scale in some places. Satisfactory crops have resulted, and Professor R. H. Stoughton, who is engaged in carrying out investigations in the process at Reading University, has recently recorded that in order to determine the nutritional value of crops so raised, 'chemical analysis of the carbohydrate, protein, inorganic constituents, and vitamin C content were carried out. No significant differences could be established between plants grown in gravel and those grown in soil.' (*Nature,* Vol. 150, No. 3797, 8th August 1942.)

The first question, of course, which springs to the mind is 'what kind of soil?' If chemically treated soil, then one would not expect to find much difference, but apart from this my reactions to these investigations are, firstly, that the results will be inconclusive until feeding tests have been carried out such as those undertaken by Dr. Rowland. It is very possible that the difference in nutritional value between humus and chemically grown plants is not, as yet, detectable by chemical analysis. It must not be forgotten that until very recently vitamins defied analysis. 'About twenty years ago I was induced to preside, during the annual meeting of the British Association, over a joint conference of its Agricultural and Medical sections arranged to discuss Vitamins. The subject was handled with considerable scepticism by the medical participants in the discussion. I well remember, prior to its taking place,' I wrote to several well-known physicians asking them their opinion on the value of Vitamins. Their replies were almost without exception hostile to their alleged efficacy, and in some cases derisory. And yet who to-day would dare to challenge the therapeutic value of these 'accessory food factors'? Viscount Bledisloe, 1940.) Secondly there is no indication at present that plants raised by soilless culture can continue to reproduce for consecutive generations. It is customary for the seed used to be raised in soil. (Mrs. Hilyer records in her book *Hydroponics* having successfully raised second generation peas and potatoes but her methods are not entirely inorganic.) Thirdly, plants grown in such very controlled and artificial conditions present a very different picture from those growing in open competition in the field. The danger of basing deductions exclusively on laboratory experiments when dealing with such natural phenomena as mycorrhizal association, for example, has already been pointed out. Of more importance to our subject therefore, is the evidence of Sir John Russell, F.R.S., late director of the Rothamsted Experimental Station. In 1939 he wrote as follows:

'We have searched diligently for evidence that organic manure gives crops of better quality than inorganic fertilizers, and so far our experiments made jointly with the Dunn Nutritional Laboratories at Cambridge, have all given negative results. No difference has yet been found.'

How can such results be reconciled with those of Dr. Rowland? I am not in possession of sufficient data to hazard an answer, but several lines of inquiry occur to me. Firstly, in this case also, no evidence is forthcoming that feeding tests were undertaken. Secondly, I would like to know the manurial treatment which the soil received in the years immediately preceding the experiments, for the effects of both organic and chemical manuring are cumulative. If the operative factor is a question of fungal activity, it is obvious that this must be so. Thirdly, I should like to know the form of the organic treatment given, for, as we have seen, not all treatments called organic do stimulate the soil population in the desired manner. (A recent visit to Rothamsted revealed the fact that no tests have been made with properly made organic compost. 1948)

It must be remembered that the inorganic enthusiasts tend to overlook in their claims that application of inorganic chemicals to a field crop does not so much test the effect of chemical nutrients as such, as of chemicals plus humus. This is why the humus enthusiasts demand long-term tests. Their view is that it is the presence of humus which softens the effects of inorganic chemicals, and the presence of inorganic chemicals that prevents compost treatment being fully effective. In other words, while it is only when the humus content of the soil becomes seriously lowered that the harmful effect of inorganics becomes *fully apparent,* feeding value nevertheless is probably affected long before this stage is reached. The only short-term tests therefore which could possibly provide a true comparison would be one undertaken with subsoil; in the one case with inorganic nutrients added, and in the other case with the addition of humus. I believe it is a fact that the seed used on the famous Broadbalk field at Rothamsted is invariably fresh seed, imported each year. This must weaken any nutritional argument based on the reaction of this seed to soil treatment, for since the effect of both organic and inorganic treatment is cumulative, it becomes more and more evident with each succeeding generation. One of the reasons for this is no doubt that continued applications of inorganic chemicals appear to have a serious lowering effect on the fertility principle, while organic treatment, as already noted in the case of sunn hemp, stimulates it. A similar result has been noted with clover by Mr. R. G. Hawkins of Braintree who writes (May 1942):

'For some years now I have inspected crops of Essex red clover and I have noted that the yield of seed is invariably higher on those farms which keep stock, so that the land receives a periodic dressing of dung. The difference is most pronounced in those years when clover seed is generally a poor crop. . . .' (Quoted from *Compost News Letter No. 3.*)

The factor responsible for lowering reproductive powers, is probably the same as that affecting feeding value. In both cases it is reasonable to assume that it is almost certainly a vital factor. The argument that living forces are unnecessary to living organisms, and that these require nothing for health, growth and vigour that could not be supplied by synthetic chemical products, will remain unconvincing until such time as scientists succeed in creating life itself. Dr. Innes Pearse maintains that the relationship of humus to the seedling, is exactly comparable to that of the placenta to the foetus. (See also Technical Ref. No. 14.) In any event, the mere fact that such startling discrepancy of view as that cited above can co-exist among scientists is in itself a sound indication of the importance of carrying out further tests.

There are very many indications now available contradicting the Rothamsted results and they are not confined to rats.

In the course of feeding trials carried out by the late Sir Bernard Greenwell at Marden Park in Surrey, in 1939, 'the effect of a grain ration raised from fertile soil was compared with a similar one (purchased on the open market) on poultry, pigs, horses and dairy cows. In all cases the results were similar. The animals not only throve better on the grain from fertile soil, but they needed less--a saving of about 15 per cent was obtained. The grain from fertile soil was found to contain a satisfying power not produced by ordinary produce. But this was not all; resistance to disease markedly increased. In poultry, for example, infantile mortality fell from over 40 per cent to less than 4 per cent. In pigs, troubles like scour disappeared. Mares and cows showed none of the troubles which often occur at birth.' (Howard, quoting Sir B. Greenwell's paper read to Journal of Farmers' Club, 1939.)

The possibility that grain grown on fertile soil might result in a quantitive saving is an important point, particularly in war-time. If a wide adoption of humus farming were to result in a 10 per cent to 15 per cent reduction in animal feeding stuffs throughout the country, a large amount of shipping space would be saved, or alternatively more livestock could be kept. These are worth-while considerations in themselves, quite apart from the economic benefit that would accrue from any general improvement in the health of our livestock, were this to result. I might remind you here how Howard found that his oxen in India, fed on compost-grown food, failed to contract foot-and-mouth disease even when 'rubbing noses' with infected animals.

In connection with this Lord Portsmouth told me an interesting story. A few years ago he approached the heads of the Government Veterinary Department, whose responsibility it is to decide on the policy to be followed during epidemics of such infectious diseases as foot-and-mouth disease. At present, as is well known, the policy in the case of this disease, is to slaughter not only all infected animals, but also all contacts, at the same time prohibiting any movement of stock in an area fifteen miles around the site of the outbreak. Anyone who has studied the outbreaks in recent years, cannot fail to have been struck by the way in which farms next door to the one where an outbreak has occurred, so often escape infection, while others, more widely separated, succumb. It is difficult to reconcile this with the official theory that the spread of infection is due to birds, or ground vermin.

Lord Portsmouth, with his personal experience of the effects of humus farming, suggested an experiment to these Veterinary Authorities, to be tried when foot-and-mouth next occurred in a suitable locality, such as the Isle of Wight, where a whole area could be effectively isolated. His idea was that instead of adopting the slaughter policy, they should prohibit any movement of stock to or from the island, and let the disease take its course, carefully noting the farms that escaped and comparing the system of farming in practice there, with that on the farms to which the disease spread. The 'vets' 'threw up their hands in horror' and said 'Do you suggest that half Europe is badly farmed?'

'Yes,' said Lord Portsmouth, 'just that.'

They then drew his attention to a large wall map. It covered the Continent from the Baltic to the Mediterranean, and from the Atlantic to Russia. It was studded with small flags, each flag representing a confirmed outbreak of foot-and-mouth disease.

Lord Portsmouth told me that he looked from this map to the 'vets' in astonishment. 'Doesn't that map show you something?' he asked.

'Only', was the reply, 'that the disease is very prevalent.'

Lord Portsmouth then told me that he had an intimate knowledge of some parts of southern Europe, and had travelled large tracts of it on foot, including the Balkans. He said that from his personal knowledge of the farming methods undertaken in this mountain area, he was able to notice that very often the flags stuck into the map stopped where traditional peasant farming began. He pointed this out to these authorities, saying, 'Do you mean to tell me that birds flying south stop when they get to this valley or that region.'

I asked him what reply was made to this, and he said: 'Oh! They just thought I was mad!'

There is nothing harder than to introduce a new idea into the official mind.

A further contribution to the indications concerning animals and artificials, is contained in the following letter to the *Spectator* of 17th October 1941, by Dr. Sanderson-Wells, Chairman of the Food Education Society.' (T. H. Sanderson-Wells, M.B.E., M.D., F.R.C.S.)

'A dig-for-victory plot on the edge of a golf-links was limed, planted and treated with artificials. Luxuriant heavy-green cabbages, sprouts and other vegetables resulted. To increase the family meat ration, part of this crop was fed to rabbits, who ate without relish, became apathetic and smelt unpleasant. When later grass mowings were substituted the rabbits ate voraciously and became vigorous and sweet-smelling.

'A correspondent writes: "Cabbages and sprouts grown too fast with nitrate and phosphate are a curious 'wrong' colour. If over 50 per cent of the greenstuff given to rabbits is of this sort the rabbits die. Permanent pasture dressed with phosphate produces a luxuriant field. If the phosphate goes beyond a certain point the field takes on an unnatural green, and is deserted by wild rabbits."

'Salesmen use this fact as a recommendation. One told me: "Use any soluble phosphate fertilizer and keep the rabbits away." Another said "Use enough nitro-chalk and you will get big greens that rabbits will scarcely touch: if they do, they die." Animal instincts may be sound guides to food values, which are actually soil values, because food is nothing more than the "conveyancing agent" or "agent of transfer" of the soil's qualities into the bodies of man and beast; land in good heart supporting bodily health, vigour and stamina; poor unbalanced soils producing ill health and debility. For instance, the liking of birds for hips, haws and many other hedgerow fruits has led to the discovery that these contain high concentrations of mineral salts, vitamins, and other essential food elements.' (Reprinted in *Compost News Letter No. 3.*)

The soundness of this idea that food is an agent of transfer for the qualities of soil has been demonstrated to me many times by my own experience in the raising of young pigs. Pigs bred under modern housing conditions (defined by someone as 'cold and concrete'), are very prone to the disease of white-scour when they reach the age of about one month. If the attack is serious it can cause considerable financial loss, even if it does not actually kill the pigs. The textbooks give the cause as lack of iron and recommend dosing with some iron preparation such as Parrish's Food; feeding such weeds as chickweed (which is rich in iron), or, as a third alternative, taking up pieces of turf and giving these to the young pigs.

I have made many experiments in connection with the curing and prevention of this trouble. From the turf remedy I tried experiments with ordinary soil from arable fields. It was not long before I found that soil gathered from a field rich in humus, where no chemicals have been applied, was quite as effective as turf, curing the pigs within forty-eight hours. Whereas soil from exhausted land, or land treated with chemicals had no effect in curing the disease. I also noticed that young pigs running in the open on good pasture, provided it was not too hard for them to rootle (as for instance in hard frost, or very prolonged drought), never suffered from this disorder. It is never a menace to my herd now under any conditions, even in long spells of severe winter weather when the ground is covered with snow and the pigs have to be entirely housed up. Under such conditions I no longer wait for the first sign of scour, but regularly collect the soil of *fresh* mole hills, newly thrown up above the snow, on land I know to be fertile. Collected daily, this soil is friable in the hardest frost, and it is equally good in very wet weather, for it is never sticky. The pigs eat it voraciously in incredible quantities, starting when about a week old. I sometimes add a little chalk to it, which the pigs seem to like.

This experience ties up in an interesting way with the research work of Baker and Martin (F. A. Baker and Rollo Martin, *Zbl Bakt. II,* 1937.) and brings us back once more to the role of the fungus. Baker and Martin have shown that a group of fungi indigenous to the caecum of the rabbit, guinea-pig, and horse is responsible for the breakdown of cellulose ingested by these animals, and their research work on the behaviour of these fungi *in vivo* has provided strong evidence for the view that their relationship to the host animal is a symbiotic one. (Some of these organisms incidentally are also indigenous to the human mouth.)

These investigators have not experimented with the pig so far as I am aware, but it is reasonable to suppose that the breakdown of cellulose in the pig's digestive tract is very probably also dependent upon the presence of fungi. It is also reasonable to suppose that the pig's gut, at birth, is more or less sterile. This being so, before he can cope with green food or cereals, he must presumably inoculate himself with appropriate fungi. If this is, in fact, what occurs, it explains the pig's very early appetite for soil. It also explains why soil heavily dressed with artificials is not effective in stopping the indigestion which causes white scour at about the age when the pig normally begins to eat green food, since in such soil fungal growth is largely inhibited.

An alternative explanation, put forward by certain medical friends, is that the scour is bacterial in origin, and that some bactericidal agency is introduced with the soil. This explanation is possible of course, and the recent discovery by an American scientist of a soil organism possessing curative powers very much akin to penicillium lends colour to the theory, but I still lean towards my own hypothesis, more particularly since research, more recent than that of Baker and Martin, has provided evidence that the digestive tract of all mammals is the normal habitat of fungus flora, symbiotic in habit, whose function is not confined to assisting the digestion of cellulose, but is also concerned with making certain vitamins available. If the initial source of fungus infection should prove to be the soil, or even natural raw herbage, one is prompted to wonder whether the inability to digest coarse natural foods, such as raw salads, and wholemeal bread, which is sometimes exhibited by modern city dwellers who have subsisted for years on sophisticated, processed and tinned foods, may not be associated in some way with faulty fungal activity brought about through the prolonged absence from their diet of those same natural foods. At any rate, in the case of the pigs, all the recent research is consistent with my interpretation, which also seems to be supported by the well-known fact that when cooked potatoes are fed to pigs they must be washed before boiling, whereas raw potatoes can only be safely fed if the soil is left on them. It would appear from this that live soil enables pigs to digest raw potatoes (in moderation), while cooked potatoes not only do not require this aid, but the soil, when sterilized, appears itself to be indigestible.

Older farm workers have told me that they never remember scour in young pigs when '*they* were young', and one of the more noticing among them told me that in his view this was because in those days when roots such as mangolds were cleaned for the cows, the part trimmed off, with the soil attached, was always thrown to the pigs, and that in 'those days, these crops were always grown with muck'.

There seems little doubt that we can make much more use than we do at present of the information which animals themselves are very ready to give us in estimating quality in food. For instance, cattle are often better judges than the chemist as to whether or not land requires liming. In the winter of 1941-2 I chalked part of a meadow which the soil experts, after analysis, told me did not require it. The following summer, and again during the summer of 1943, the verdict of the cattle was very different; that part which received chalk was grazed as close as a billiards table. The rest was fed off only when there was nothing left on the chalked portion.

The Rev. Willis Feast, of Booton, Norwich, records how a young farmer told him that he grew Swedes, some with and some without artificials : 'He fed the "withouts" first, and when they were finished had the greatest difficulty in persuading his beasts to start eating the "withs".' (*Compost News Letter No. 3.* See also Chapter IX.)

The preference of cattle for mucked or composted pasture is very marked. Howard describes a case of this kind which he was able to observe personally, since the six fields in question were in front of his house at Heversham. 'All are first-class rye pastures,' he writes, 'with nothing to choose between them as regards soil, aspect or drainage. Nevertheless in 1941 the sheep and cattle, which had access to all six fields at the same time, consistently neglected one of them, the grass of which was allowed by the animals to grow at will. This particular field alone of the six had received a large dressing of artificials.'

One winter I noticed that the farm cats refused potatoes boiled for the pigs when these had been purchased from a grower who uses artificials, but that later in the season, when I started to use the small potatoes from our own crop, grown with humus, the cats ate them with avidity.

Stories such as these are indications, because they are reported from so many different quarters. They are not proof, because they have not been reproduced to order under strictly controlled conditions. I must confess, however, that my own personal taste entirely concurs with that of the animal. To me the flavour of vegetables grown with farmyard manure, and more particularly compost, is noticeably superior to that of the same vegetables grown with chemicals. It would be in keeping with nature's usually sensible arrangements if palatability were to prove an indication of nutritional value. Unfortunately, in so far as civilized man is concerned, such guides are no longer reliable, generations of faulty feeding having developed in us a liking for many things that do us little good, such as refined sugar and white flour. The natural choice of animals, however-even domestic animals-is almost certainly worth noting, and investigations based on it would probably yield interesting results.

The examples just given of animals obviously preferring compost-grown food, coupled with the experience of Sir Bernard Greenwell and others, that a smaller quantity of such food is required to produce a given increase in weight, certainly suggest that such food is more complete and balanced.

A doctor of my acquaintance holds the view that, 'It is a likely hypothesis that the appetite-satisfying qualities of compost-grown food are due to a greater content of hormones and vitamins. Similarly when the vitamin content of such a food as bread, for instance, is deliberately strengthened by the addition of extra germ, provided that that is fresh and, except for the baking, raw, its power of satisfying hunger is notable.'

This doctor lives in Cheshire, a county where, before bread rationing, a special wholemeal bread was available. This bread was known as 'Fertility Bread'. It was made from locally grown wheat; about 66½ lb. of the latter with about 33½ lb. of raw wheat germ added, and was baked within thirty-six hours of the meal being ground.

He told me the following story as an illustration of the satisfying power of this bread.

'One rainy night, called to a distant and unknown patient, I returned from a fruitless inquiry to find a man standing by my car in conversation with my wife. She was saying--"I call a 4½d. loaf expensive." And his reply was, "Well, I don't, Mrs.-- -- You see I put it this way: I can make a good meal on half a fertility loaf and nothing more except the butter and perhaps a lettuce; and I am satisfied. That's 2¼d. aside from the butter and so on. But if I must have white bread I want as much and more, and a piece of beef or a chicken's leg as well; and against I've done, my dinner's cost me more than double."'

This same doctor used a vivid analogy to illustrate the same theme. He likened an attempt to satisfy hunger on white bread, to eating Christmas pudding with intent to find the threepenny bit. 'It is not in the first helping, so you have another, after that you feel full, but though you do not really want to eat any more, you go on because you are still looking for something which is not there.' This analogy also expresses my theory of the susceptibility of chemically grown vegetables to caterpillar and insect attack. For example, a commercial tomato grower carrying out an experiment recently between a tomato house treated with compost only and one treated with compost plus chemicals noted a greater *number* of white-fly in the compost houses but *no* visible injury to the plant or staining on the fruit, while in the other house, the fruit was so badly stained that every tomato had to be wiped although the number of insects present was visibly less. If the vegetable lacks something which the caterpillar or insect needs, he may go on eating long after satiety in an effort to find it. As already stated, this is a purely personal hypothesis. I have no proof that it is so, it merely seems to me probable in view of the evidence available.

III
MAN

If it should be conclusively proved that humus, whether through the agency of soil fungi or otherwise, can restore to plants some virtue otherwise missing, something which can best be summed up in the word 'quality', embracing as it would seem, palatability, keeping quality, and health, and that such plants do act as a conveying agency, passing on this quality to animals; then the foundation would be well and truly laid for further investigations as to the extent to which this same quality can be further transmitted to the human race. The claim that it can be so transmitted has already been made, but the moment we attempt to provide evidence involving human beings, we are faced with a much more difficult task, critical proof is almost impossible to obtain, for you cannot treat people as though they were laboratory guinea-pigs. Nevertheless many indications supporting the claim do exist, and a few examples must be given.

In many districts of India rice is the staple diet. I have been told that in those areas where the rice crop is sown broadcast in the paddy fields, the standard of health of both crop and population is low, but that in other districts where it is the custom to sow the rice in a seed-bed of soil rich in humus, and thence to transplant the seedlings, both crop and people are remarkably healthy.

That the incidence of malaria may also be connected with methods of crop cultivation is indicated in the following quotation.

'There are multitudinous examples of the retreat of the crop and of the animal and of mankind before the parasite, but we are only now beginning to get examples of the reverse process. In two cases--malaria and sleeping sickness--there are signs that soil fertility is the real method of dealing with these diseases.

'I will take malaria first. In one of the most intensely malarious areas of India, the Terai--a strip of forest at the base of the Himalayas--malaria is so bad in the early rains, June to September, that it is regarded as a death trap both by Europeans and Indians. Nevertheless, in this area a tribe exists who are practically, to all intents and purposes, immune to malaria. They go in for intensive agriculture and their villages are very clean. . . . What we want is a McCarrison to follow this clue out still further. That malaria depends on the way crops are grown is supported by other facts. In Western Bengal where rice is not properly grown, there is intense malaria; in Eastern Bengal (Mymensingh) where rice is exceedingly well grown, there is very little malaria. Further, in the rice areas, when these are invaded by the water hyacinth, the conditions for malarial mosquitos seem to be removed. Incidentally the water hyacinth will provide the humus needed to grow rice really properly.

'As regards sleeping sickness, the evidence is not so complete: never, the less it exists. In Nigeria it has been found that the use of cattle manure for raising fodder crops is followed by a distinct increase in resistance to the Tsetse fly disease. There are some indications that the same thing occurs in Tanganyika. What we really need in the fly belt of Africa is a fairly large area of really fertile soil, so that we can see what the effect of this is on the incidence of sleeping sickness. (*Compost News Letter No. 2,* Howard quoting Major Clyde's report.)

In East Africa 'Major Layzell found that the vegetables grown for his labour force on the land manured with humus, made largely from sisal waste, resulted in a marked improvement in the general health, physique and efficiency of his workers. The men performed their tasks much more easily than was the rule before the new system of nutrition was introduced. Major Layzell is now engaged in starting this work at a new centre.' (Howard, Letter to *The Times,* 10th August 1939.)

Corroboratory evidence comes from a large preparatory school near London at which both day boys and boarders are educated. The vegetables consumed in the school are provided from its own garden. Until a few years ago these were raised with artificials, then a change over was made to Indore compost. The head master records the result as follows:

'Formerly, in the days when artificials were used, cases of colds, measles, and. scarlet fever used to run through the school. Now they tend to be confined to the single case imported from outside. Further, the taste and quality of the vegetables have definitely improved since they were raised with compost.' (Personal letter to Sir Albert Howard from the Head Master concerned.)

This experiment is of particular interest when it is considered in conjunction with a somewhat similar one undertaken in New Zealand. The truly devastating effects of soil exploitation, past and present, are nowhere more evident than in that beautiful Dominion.

Mrs. Ysabel Daldy, founder of The Physical and Mental Welfare Society of New Zealand Incorporated, has been kind enough to supply me with the official facts, figures, and statistics which fully endorse this statement. 'With a perseverance worthy of a better cause' she writes in a summary of the situation, 'New Zealand has for years past been carrying out a nation-wide experiment whose outcome has proved beyond reasonable doubt that a people reared upon eroded and otherwise exhausted soils becomes a people whose condition gradually deteriorates.' She quotes Professor Worley, M.A., D.Sc. (Chief of the Department of Chemistry, University of New Zealand) as stating that when New Zealand was first colonized the country was 'almost entirely covered with rich vegetation, chiefly forest, which covered the hills and extended up the mountain sides to a height of some 3,000 to 4,000 feet. The floor of this forest was a porous layer of priceless humus, the product of thousands of years of formation. In this humus were the mineral salts extracted from the subsoil and the rocks, by the roots of the plants and trees. In our unthinking exploitation of the land we have destroyed the forests over the major portion of the country and millions of pounds' worth of soil fertility have been sent sliding into the sea by erosion--one of the consequences of deforestation.'

'The whole of New Zealand food supplies', writes Mrs. Daldy, 'are now grown from soils manured with ordinary chemical fertilizers,' and gives Professor Worley's comment on this practice.

'By what we add, as well as by what we fail to restore to the soil, we are profoundly affecting its chemical composition, its biological content and its physical nature. We are thus affecting the quality of the food grown on such soil, and, in consequence, the health and vitality of the population. It is now recognized that much of our food has serious deficiencies, and that very many of our ills are due to this cause.'

What are these ills? It is said that figures speak; in New Zealand they shout. During the twenty years between the two world wars New Zealand's population (by births and immigration) increased 36 per cent. In the same period the birth-rate decreased from 23 to 17 per thousand of the mean population; mental cases increased by 100 per cent; and admissions into public hospitals showed a gradual increase up to 126 per cent. Maternal mortality is a little higher in New Zealand than in Great Britain. Infant mortality is certainly the lowest in the world, but the incidence of illness among New Zealand toddlers between two and five years of age is alarming. Every year, of children of pre-school age, some 80 per cent are found to be physically defective in some way.

Of every hundred children who enter New Zealand schools fifteen show signs of needing medical attention, fifteen need observation, many show signs of nose and throat trouble, and at least two-thirds have dental caries. In this connection, the New Zealand Ministry of Health has published the fact that 30 per cent of all pre-school children suffer from nose and throat troubles, 23 per cent suffer from gland troubles, and 2 per cent have some form of lung trouble. The official figures for illnesses among children at school are: 5 per cent suffering from enlarged glands; 15 per cent suffering from incipient goitre; 15 per cent suffering from enlarged tonsils; 32 per cent suffering from dental caries; and 66 per cent suffering from other physical defects.

Lord Bledisloe reports that during his term of office as Governor-General of New Zealand he ascertained that about 60 per cent of the inmates of the Dominion's public hospitals had previously suffered from malnutrition. He has also stated that 'for many years natural soil deficiencies have caused widespread animal disease, bush-sickness being found traceable to a lack of iron and cobalt, dopiness in sheep to a lack of lime, Waihi disease to a lack of phosphates, and goitre to a lack of iodine.'

Mr. H. B. Tennent, the agricultural editor of *The Weekly News* (New Zealand's leading agricultural journal), wrote in 1938: 'Of all primary producing countries in the world, New Zealand is probably most lacking in some important soil elements essential to healthy plant and animal growth. Animal sicknesses and the rapidly increasing populations of hospitals and mental institutions can in a great many cases be directly traced to mineral and other deficiencies in the foods produced from improperly balanced soils.'

It was against this background that Dr. G. B. Chapman (of the Physical and Mental Welfare Society of N.Z. Inc. Now the President of the N.Z. Humus Society.) carried out a notable feeding experiment. An article by Mrs. Daldy describing it, appeared in the issue of *Nature* for 8th June 1940, and I am indebted to the editor of that journal, as well as to the author, for permission to quote from it. It was begun in 1936 at the hostel of the Mount Albert Grammar School, the second largest grammar school in the city of Auckland. The subjects were 'some sixty boys, teachers and staff'.

'At the time of the inception of the experiment,' writes Mrs. Daldy, 'the dietary at the hostel was liberal, being well above the customary standard for boarding-schools; yet the boys consistently suffered (as was the case in other New Zealand schools and institutions) from colds, catarrh, septic tonsils, epidemics of influenza, dental caries, and other preventable complaints. . . .

'Dr. Chapman opened his campaign in 1936 by delivering a few short lectures to the resident teachers and boys, advising the growing of the hostel's fruit and vegetables from soils to be treated by properly prepared humus. He was successful in arousing the interest of the teachers, the boys, the matron and the staff. The reform was put in hand and the change made from "chemically grown" fruit, salads and vegetables to the "naturally produced" foods now in use.'

Since much of the boys' food, such as meat, bread, etc., had still to be obtained from outside sources, this portion of their diet continued to be the produce of 'depleted soils'. Dr. Chapman therefore gave the boys a daily extract of vitamins A and D to counteract the deficiencies in these foods. The Matron of the school has submitted a report on the results of the experiment.

'The first thing to be noted,' she wrote, 'during the twelve months following the change-over to garden produce grown from our humus-treated soil, was the declining catarrhal condition among the boys. Catarrh had previously been general and, in some cases very bad among the boys. In specific cases the elimination was complete. There was also a very marked decline in colds and influenza. Colds are now rare and any cases of influenza very mild. Coming to the 1938 measles epidemic, which was universal in New Zealand, the new boys suffered the more acute form of attack: while the boys who had been at the hostel for a year or more sustained the milder attacks, with a much more rapid convalescence.

'During the past three years there has been a marked physical growth and development during terms of heavy school work and sport' (actual heights and weights are quoted). 'In some cases boys go through a period of indisposition for several weeks after entering the hostel. This would appear to indicate that the method of feeding causes a certain detoxication period which when cleared up does not return. Excellent health gradually ensues in all cases, and is maintained. There are fewer accidents, particularly in the football season, which would possibly indicate that the foods in use contain the optimum amount of minerals and vitamins, thus ensuring a full development of bone and muscle and a greater resiliency to fracture and sprains. The satisfactory physical condition described is maintained during periods of rapid growth and development of mind and body. Constipation and bilious attacks are rare. Skins are clear and healthy, while the boys are unceasingly active and virile.

'Since the change to naturally grown garden produce, the periodical reports in regard to the boys' dental condition have been more than gratifying.' (At the beginning of the war 40 per cent of the recruits volunteering for New Zealand's armed forces were temporarily rejected because of the condition of their teeth.)

It may be argued that the remarkable improvement in health brought about by this experiment was due to the vitamin treatment and not to the altered method of vegetable culture. Obviously further experiments are required to provide definite proof on this point, but when considered in conjunction with other evidence presented in this chapter, particularly the cases immediately preceding and following this New Zealand example, and when due weight has been given to the proved deficiency in so much of New Zealand's soil, then it must be conceded, I think, that Dr. Chapman's experiment serves considerably to strengthen the indications.

My next example is also of more than usual interest, for it comes from Dr. J. W. Scharff, who until the tragic fall of Malaya was Chief Health Officer at Singapore. Here is his first hand account as published in *Mother Earth,* the journal of the Soil Association.

'The editor of this magazine has kindly invited me to record the sequel to my wartime effort of introducing the Indore method of composting into the village life of certain communities in Malaya.

'The interruption of these developments following the Japanese invasion is so complete that the picture now presented is almost the reverse of what was then in progress. It therefore remains for me to describe the story of the experiment and to amplify some of the reasons which lead me to the conclusion that there must be exceptional quality in fresh compost-grown foodstuff. I believe that the further development and understanding of this subject is of the utmost importance.

'The original intention of the experiment had been to prepare Singapore and neighbouring territories against the advent of war by increasing food production. It was evident that if organic wastes could be fully utilized in compost-making, the danger of starvation in the event of a blockade around the coast of Malaya might be reduced.

'From January 1940 until January 1942 I therefore had a unique opportunity, due to wartime needs, of watching the progress of a campaign for growing vegetables, and seeing that they were eaten by a labour force of nearly 500 Tamil coolies. These men were employed by the Singapore Health Department in various parts of the island of Singapore.

'As soon as England became involved in war this emergency made it possible to allocate an area totalling about 40 acres of vegetable allotments on favourable terms to men engaged in sanitary duties. My labourers were granted these allotments on condition that they prepared compost and used the vegetables and fruit grown therein for themselves and their families only. Sale of the produce was not allowed. Thus it was ensured that these goods were used at home. The local Agricultural Department lent their inspectors and staff to teach the men how best to grow vegetables, and demonstrations in cooking and preparation of the foodstuff were organized for each of the labour settlements. Compost-making was started on a large scale and during the months previous to opening of the campaign a supply of over a thousand tons of compost was ready to launch this experiment.

'During the course of the ensuing months, apathy and indifference on the part of the labourers gave way to interest and enthusiasm as soon as it became apparent how well plants would grow on soil rendered fertile with compost. A number of vegetable shows were arranged, at which the healthy produce of fertile soil was exhibited and prizes were awarded. Within six months the accumulated stocks of compost were used up and more active steps were taken to augment the supply as well as to satisfy the growing demands of other enthusiastic gardeners inspired by the achievements of my men.

'At the end of the first year, it was obvious that the potent stimulus to this endeavour was the surprising improvement in stamina and health acquired by those taking part in this cultivation. Debility and sickness had been swept away, and my men were capable of, and gladly responded to, the heavier work demanded by the increasing stress of war. But for the onslaught by the Japanese which overwhelmed Malaya, I should have been able to present a statistical record of the benefit resulting from this widespread effort of vegetable culture on compost such as would astonish the scientific world. The results were all the more dramatic in that I had not expected this achievement.

'The numbers taking part in this venture were so large as to preclude any possibility of mistake. It might be argued that the improvement in stamina and health amongst my employees was due to the good effect of unaccustomed exercise or to the increased amount of vegetables consumed. Neither of these explanations would suffice to explain the extent of the health benefit observed amongst the women, children and dependants of my labourers who shared in this remarkable improvement.

'Shortly before the tragic disaster which brought Singapore within the hateful grasp of the Japanese invader, it became apparent that the health of men, women and children, who had been served consistently with healthy food grown on fertile soil, was outstandingly better than it was amongst those similarly placed but not enjoying the benefits of such health-yielding produce.

'The scene on my return to Malaya with our victorious army early in September 1945 was vastly different from that which was observed during the previous period of plenty and prosperity. Most of the labourers employed in scavenging, and their families, had been obliged to leave their homes to seek other work. Many were ensalved by the Japanese for enforced labour on the railways in Siam. Soil cultivation was neglected and there was no security for those who attempted to carry on. Produce was stolen and equipment destroyed; misery, sickness and starvation stalked throughout the land.

'This is the broad outline of the passage of events up to the time of our triumphal re-entry into Singapore less than a year ago. Since then, thanks to the energy and enthusiasm of my colleagues, a great deal has been done to repair the devastation and to revive the organization which yielded such satisfactory results. Still many more years of toil and effort will be needed to approach the point at which the foregoing experiment on soil cultivation can be repeated in Malaya. In the meantime, there is urgent need of better knowledge of the underlying principles in the health benefits coming from fresh food grown in compost-fed soil.

'Mr. Donald Hopkins (*Chemicals, Humus and the Soil.* Donald P. Hopkins, Faber and Faber, 1946.) has recently questioned my conclusion that these good effects were attributable to the compost, and suggests that vegetable produce grown in any other way might have given equivalent results. Such criticism is welcome if it leads to further investigation on compost-grown foodstuff, which the Soil Association so urgently desires; so it may be useful to take this opportunity to point out that my observation was made upon a stable labour force, consisting of men who had been in regular employment for many years. Malnutrition had not previously been apparent amongst them, and there was no shortage of ordinary vegetable produce in the village markets. The women and children were in regular attendance at rural welfare centres, and the men were in receipt of a regular salary amply sufficient to satisfy their needs. The reason for my insistence in getting them to grow and eat compost-grown vegetables was to promote a system of sanitation which would make the community, as nearly as possible, self-supporting when the tide of war spread against Malaya. The healthy response which eventually greeted this undertaking was unexpected, and was one which I had not hitherto experienced in many years of trial on the means of improving public health. The conclusion that "an oasis of food health had become established founded upon a diet of compost-grown food" therefore rests upon a firm foundation. At the present time, when shortage of food supply is a major issue, this lesson of Malaya's wartime experience is one which should be considered and confirmed by further studies.'

I hesitate to advance my own personal experience among these examples, but I have decided to do so for two reasons. Firstly, because I think it merits the appellation of an 'indication', and secondly, because people who recommend any course of human action or behaviour which lays itself open to the accusation of claiming to be a 'cure-all', so often appear to others to be themselves more than usually in need of the 'cures' they advocate. I feel therefore that I owe it to my readers to forestall the question, 'Have you tried it on yourself?'

I have lived a healthy country existence practically all my life, and since 1918 I have been actively engaged in farming. I am physically robust, and have never suffered a major illness, but until 1938 I was seldom free from some form of rheumatism, and from November to April I invariably suffered from a continual succession of head colds, while my annual visit to the dentist always involved a series of 'stoppings' and occasionally an extraction.

In 1938 I was introduced to the humus theory, the McCarrison experiments, and the effect on health of 'whole' diets as described by Dr. Wrench in *The Wheel of Health.*

In so far as I was able I immediately put the theory into practice. I started to make compost by Howard's method using it first on the vegetables for home consumption. After harvest I saved some of my wheat crop from a field which for several seasons had received only farmyard manure. This I ground, just as it was, on the ordinary farm mill kept for grinding grain for livestock. Thereafter, in place of the baker's loaf, I ate home-made bread baked from this home-grown, home-milled, whole wheat.

That winter, 1938-9, I had no colds at all, and almost for the first time in my life was free from rheumatic pains even in prolonged spells of wet weather.

In 1939 the only wheat available was grown on rather poor soil deficient in humus, and that winter, 1939-40, much to my annoyance and disappointment I had a slight return of winter rheumatism and caught three colds. But it was the first war winter. Rationing and other restrictions had been introduced, and thus there were other differences in my diet. Notably, less butter (for we did not make it) and no cream, previously plentiful. I therefore thought it probable that if my partial relapse was due to diet at all, any, or all of these differences might be responsible.

In 1940 I was once more able to save wheat for home baking that had been grown on fertile soil. Restriction in other portions of my diet of course remained. That winter, 1940-1, my rheumatism, except for one short attack lasting about a week, again disappeared, and I caught one cold only, and this despite exceptionally long working hours by day, and nights constantly disturbed by civil defence duties. Up to the time of publication (Autumn 1943), this state of good health has continued. I have had no colds or rheumatism this winter.

Now as to teeth. I had my usual crop of stoppings in the summer of 1938. A year later, during the autumn of 1939, for the first time that I can remember my dentist could find nothing to do. I did not visit him again until October 1942. All that then needed to be done, after this interval of four years, was one small stopping in a place where an old filling had worn away.

I do not claim for this experience that it provides anything in the nature of proof (though it certainly provides me with every inducement to continue to eat compost grown food). The interest lies in the fact that this is a case in which no change took place in the articles of diet, only in the way in which they were grown.

Lastly, I conclude this list of indications by quoting three cases experienced by members of the Panel Committee of the Doctors of Cheshire, as reported in the references to the Medical Testament. These cases are of great interest, especially the first, which is I think the most complete account of a whole diet experiment yet to be recorded in this country.

EXPERIENCES OF MEMBERS OF THE COMMITTEE

'These have no pretensions to be scientific research but are submitted as examples of the effects of diet noted over and over again in ordinary family practice.

A

'The reality of the value of using fresh, well chosen food is shown in a practice in a Cheshire village. The County ante-natal scheme makes provision for a woman's own family doctor to supervise her in pregnancy. Her nutrition is his first concern. In the village referred to the local Mothers' organization conducts a "child-welfare" each month to which the local doctor is honorary M.O. A fair percentage of the mothers of the neighbourhood, mostly, but not all, his patients, attend and thus receive his advice upon the nurture of the children some eight to twelve times a year; and a thorough mutual understanding has grown up. The food of the mother, during her pregnancy, is wholemeal bread, one to two pints of milk (raw), generally including half a pint at breakfast taken with porridge (medium oatmeal scattered into boiling water and stirred till it thickens); eggs are used freely; salads in abundance, including celery and dandelion leaves; green leaf vegetables plunged into boiling water for five minutes and eaten with butter or poached eggs-or with meat, but the amount of meat taken is very moderate; liver weekly; herrings twice or once a week and a little cod liver oil except on herring days; fruit in abundance-such is an outline of their food. The evening meal is often begun with soup of the Scots broth type, but carrots, unpeeled, are grated into it just before serving. Apples are eaten in their skins or baked in their skins, and other fruit is used freely. Potatoes are baked in their skins or boiled in their skins (dropped into boiling water and boiled till they "smile", then the water is poured off and a crumpled cloth put in the pot whilst it is drawn to the side of the fire). Cheshire cheese, grated into a salad, with a hard egg, is advised and popular.

'The wholemeal bread in question is fertility bread, that is, locally grown wheat, ground (or rather dashed to pieces by a steel fan revolving 2,500 times a minute) in a local mill, mixed with half its weight of raw wheat germ fresh off the rollers of a Liverpool mill and--a point to be rigidly insisted upon--baked at once, within thirty-six hours at most--a rather close but very palatable bread, requiring no little skill in baking, though a number of bakers in the neighbourhood have acquired it.

'If her haemoglobin be 80 per cent or under, the mother receives iron, ferrous sulphate, or other.

'With rare exceptions, and those almost always "strangers", the mothers feed their infants at the breast nine months and then wean them by a year or a little more. The nursing mother's food continues as in pregnancy, including the greens and salads. The feeding times are 6 a.m., 10 a.m., 2 p.m., 6 p.m. and 10 p.m.--and very seldom in the small hours.

'The children begin to bite the wholemeal crusts at from seven to nine months and then often get a little raw turnip juice made by putting Barbados sugar (Muscovado) into a hollowed out swede or other turnip.

'Except custard (egg and also "beast milk") and junket, no milk puddings are used, except when occasionally rice which still has its germ and silver skin, can be obtained. Ordinary rice is discouraged.

'Furmity (Frumenty) is not yet forgotten by the indigenous people and its use is encouraged.

'No patent or "processed" food of any kind whatever is employed, with the exception of Marmite and of dried yeast.

'Broth, red gravy, brains and marrow bones are used for the children from nine months onwards.

'The children are encouraged to go barefoot, which suits them well; but only a very few of the mothers, so far, are entirely cordial about this.

'When the regime grew up little by little, many years ago, there were a thousand minor difficulties; fruition was slow. But it has now been established long enough for the generation it has fostered to be studied.

'The teeth are a good index of the fidelity of the mother in carrying out the regimen, both before and after the baby was born; and it may be said that perfect sets are becoming more common.

'The children are splendid. As infants they sleep as well as could be wished, grow well, are not over fat but weigh well and very seldom "ail anything". Broncho-pneumonia, for instance, is almost unknown amongst them. One of their most striking features is their good humour and happiness. They are sturdy-limbed, beautiful-skinned, normal children.

'It is not desired to give the impression that the child population of this village is perfect or that complete compliance with the dietary advised is secured even amongst all who attend the centre; but it is a fact that the mothers follow it substantially and with good results, which those concerned think they recognize.

'The benefits are visible in the households. "We have all taken to brown bread now; and I'm sure we're the better for it."--"No white bread comes in this house: it's all wholemeal and there's no trouble with constipation."--"We've got that fond of the meal bread that when we went to the seaside and they gave us white we all looked at each other!"- -And a number of families seriously cultivate their gardens for growing a succession of saladings.(Proper compost making is fostered in the cottage gardens. Instruction in how to make it is given, and garden competitions are held for the best vegetables grown with compost. Author.)

B

'A young woman, town bred, resident in a large public institution where she was a technical instructress, married a farmer. That is to say she passed from a ménage where white bread and contract butter were the invariable rule whilst green vegetables were the rare exception and subjected to prolonged cooking in steam jacketed pans at that, to one where good fresh food was available if trouble were taken. It was taken; but it was too late. Anaemic and constipated as she was, her pregnancy confirmed the fear that she was in no fit state to become a mother. Despite all efforts she passed through the kind of experience which seems to justify the notion that to be gravid is to be ill. All forms of the toxaemias of pregnancy, anorexia, hyperemesis, albuminuria and oedema were exhibited by turns; and a foul otorrhœa of old standing awoke to virulent activity. Despite all this she arrived at term and underwent an anxious, lingering and difficult confinement. The infant, resuscitated by prolonged artificial respiration, was sickly and emaciated. His respirations were intermittent and after some sixty hours he breathed his last. The mother was febrile and exhausted, her condition anxious; but she hung on to life and almost imperceptibly her condition drifted--or rather was led, for she was surrounded by the utmost solicitude--into a slow convalescence.

'All this detail has been related as a contrast to the sequel. Being active-minded she began to take a quickened interest in her surroundings, the farm. Little by little she came to do a real share of the normal work of a country-bred farmer's wife. Strength and the look of health came to her. The improvement was not fortuitous. It was decided from the start that a real attempt should be made to rebuild her physique. Her food was the fertility bread, farm or Empire butter, salads in variety and abundance, with grated carrots, soup and barley, potatoes in their jackets and unlimited fruit. Marmite and dried yeast were used. She took about a quart of milk a day fresh from their own cows, and she gradually came to take as many eggs as she wished, herrings freely and occasionally liver. She enjoyed life and it was obvious in about a year that she was in abounding health.

'Then she announced that she was again pregnant. A time of excellent health followed, no drawback. The confinement was normal, birth being spontaneous. The baby was in first-rate condition, lactation was established and maintained fully and easily for over nine months, finishing finally in about a year. With the exception of a mild influenzal attack, the mother's health has been good. Furthermore, the chronic otorrhœa of many years' standing has at last dried up.

'The baby is as good, physically and in morale, as could be wished.

C

'In May 1938 I was consulted by a young Irishman. His age was about twenty-three. He complained that he was "very poorly and had been sick and vomiting for three days". I found he was suffering from catarrhal jaundice. He had come over from the West of Ireland two months previously and was employed on a road construction scheme in Cheshire.

'I questioned him about his diet. I found that his breakfast consisted of bacon, white bread and tea. His dinner he took to his work and was mainly sandwiches of white bread and ham or beef with tea, and his evening meal was white bread and butter, sometimes an egg, and sometimes a bit of meat and tea.

'My examination revealed to me, despite his illness, a physique and an alertness of mind and body which it was a delight to behold. He was well over six feet in height with jet black hair and a ruddy complexion, and in his jaws there were thirty-two healthy and symmetrical teeth. He possessed a supple body and limbs of good proportion, and apart from his gastric condition was of sound constitution.

'I thought him to be as fine a specimen of humanity as I had ever seen. He aroused my interest and I wondered how had such a body been nurtured.

'On inquiry, he informed me "they were very poor in the west of Ireland and food was very poor indeed". "What did they have for breakfast?"--"Porridge and milk and a little bit of fat bacon."

'"What did they have for dinner?"--"Porridge and milk and a little bit of fat bacon, buttermilk and potatoes, and sometimes broth." His mother made grand broth of vegetables which they grew in the garden--carrots, turnips, potatoes, green vegetables.

' "What did they have for tea?"--"Oatcakes, scones and butter with milk and plenty of buttermilk, sometimes a little tea with bread and eggs." On further inquiry I found they might have an old fowl with bacon and potatoes for their Sunday dinner. "His mother made very good gooseberry and blackberry jam."

' "Did they have any fish?"--"Oh yes, they always had a bit of dry salted fish and as they lived near the river they sometimes got a bit of salmon." "They had very little meat, but they could always get a rabbit." "The potatoes were often baked for supper."

'It would appear that his body had been nurtured on the natural products of the west of Ireland.'

What happens when complete communities live for successive generations on whole diets raised on fertile soil will be described in the next chapter.

Note

The main argument developed in this chapter is that disease resistance, in so far as it is due to the immunity of the host, depends on the ability of correctly nourished tissue to prevent the successful attack of pathogenic organisms. It is fully realized, however, that immunity may also follow when the medium is rendered unfavourable to the growth of pathogens owing to the activities of other organisms, whether by competion for nutrients, or by the production of inimical by-products. Recent researches on certain moulds--e.g. species of *Penicillium*--suggest the possibility that factors responsible for the increased disease resistance observed in compost grown plants may be connected, in the broadest sense, with the ecological inter-relationships and activities of members of the soil population. At present one can only surmise that such factors may also be operative in the animal kingdom.

CHAPTER VII

WHOLE DIETS

'A sense of the whole is a sign of a sound mind,
and there is nothing more to be desired at the present moment.'
Plato

In the Introduction to his book, *The Wheel of Health,* (Unless otherwise stated, all quotations in this chapter are taken from this book.) Dr. Wrench makes this thought-provoking statement: 'After debating the question--Why disease? Why not health?--again and again with my fellow students, I slowly, before I qualified, came to a further question--Why was it that as students we were always presented with sick or convalescent people for our teaching and never with the ultra healthy? Why were we only taught disease: why was it presumed that we knew all about health in its fullness? The teaching was wholly one-sided. Moreover, the basis of our teaching upon disease was pathology, namely, the appearance of that which is dead from disease.'

This view, that the professional attitude to sickness is one-sided is shared by the compilers of the P.E.P. Report (1936) on the British Health Services. The authors express it as follows:

'Health means more than not being ill. A new attitude is needed, involving not so much a departure from the old as a more thorough grasp of the different elements in health policy. Many people are at any given moment suffering from defects, injuries or sickness so pronounced as to make them unable to carry on ordinary occupations and leisure activities. These are the "cases" with which a large part of the organized health services mainly deal. But in addition there are far larger numbers of people suffering temporarily or permanently from less acute defects, injuries, or inadequacies, which are not sufficient to unfit them for work or play, and may not even be noticed at all, but nevertheless suffice to place them in an unnecessarily weak position for creating and maintaining good physique, energy, happiness, or resistance to disease. . . . No contemporary health policy can be considered adequate which does not deal with the second group as well as the first. . . .

'While efforts at effecting the cure of diseases cannot be relaxed, efforts at prevention of ill health can and must be increased. The aspect of raising standards of nutrition and of fitness should be given much prominence. Health must come first: the mere state of not being ill must be recognized as an inacceptable substitute, too often tolerated or even regarded as normal. We must, moreover, face the fact that while immense study has been lavished on disease no one has intensively studied and analysed health, (One such intensive study now exists. See *The Peckham Experiment,* Pearse and Crocker. Allen and Unwin, 1943.) and our ignorance of the subject is still so deep that we can hardly claim scientifically to know what health is.'

The theory which I have endeavoured to expound in this book is that the only true conception of health is one of wholeness, dependent upon both the continuity and the completeness of the cycle of life. I shall make no attempt to discuss the philosophical aspect of this conception, I am concerned only with presenting certain evidence suggesting that it is biologically sound. For the sake of clarity in this presentation, the argument has been divided into two parts. The first states that the determining factor in health is food, and the second suggests that the health giving property of food is dependent on the way it is grown, prepared and consumed.

There is always an inherent danger in making arbitrary divisions where no true division exists, but in the present case this could hardly be avoided. The risk of failing to see the wood for the trees must sometimes be taken in order to discover how large a number of trees go to make a wood. In the previous chapters--to pursue the same analogy--I have invited you to examine some of the trees. In this chapter I want you to take a look at the wood as a whole. This, research has, so far, largely failed to do. Research workers in chemistry, biology, mycology, botany, veterinary science, and medicine, have for too long been working in watertight compartments, each busily dissecting his own tree, until in the process the wood has become so sadly dismembered it is small wonder that we sometimes cease to be aware of its existence.

It may be objected that I have followed their example of fragmentation in laying so much stress on the role of the fungus in nutrition. In so far as this accusation is well-founded, my defence is that this is the link in the life cycle which is most frequently omitted, but which is at the same time the easiest to restore. In emphasizing its importance, however, I have never intended to suggest that it forms other than a part, however important in itself, of the complete cycle of nutrition and health which is wholeness.

McCarrison in the Cantor Lectures states that 'The diet of the Sikhs is only health-promoting so long as it is consumed in its entirety', and, as Dr. Wrench points out, with their whole diet these people 'have preserved the wholeness of their health, a thing which we have failed to do'.

'In the writings of the scientific experts on nutrition, there are very numerous part-diet experiments based on synthetic or specially made-up diets, omitting or cutting down the quantity of one or more of the factors which compose a diet. One scientist will cut down the quantity ol protein given and watch the effect of this upon animals; another will cut down the fats and note the resulting sicknesses; another will give vegetable or irradiated vegetable fats in place of customary animal fats; another will give a diet in which vitamin A is defective, B is defective, C is defective, and so on.

'The experiments are skilfully devised and carried out with consummate technique. They lead to a mass of knowledge about proteins as things in themselves; fats as things in themselves; vitamins as things in themselves; but whether these can be things in themselves and are not really relative to a host of other conditions in nutrition is as yet scarcely considered. . . .

'Our health or wholeness has fragmented no less than our diet. A swarm of specialists have with the invention of science settled on the fragments to study them.

A great deal is found out about each several disease; there is a huge, unmanageable accumulation of knowledge, and this and that disease is checked or overcome. But our wholeness has not been restored to us. On the contrary, it is fragmented into a great number of diseases and still more ailments. We have lost wholeness, and we have got in its place its fragmentation with a multiplexity of methods, officially blessed and otherwise, dealing with the fragments in their severalty.'

This fragmentation has resulted, among other things, in a host of contradictory views among dietitians, each one of the different diets advocated possessing a company of followers ready to argue its exclusive merits with almost religious fervour. Thus you have the vegetarian; the fruitarian; those who never eat proteins and starch at the same meal; and those who stew all their foods together in the same pot; those that say you must drink before meals; others that believe in drinking after meals; those that drink between meals, and besides all these, and many more, there is the vast majority that eat what they want when they want it (or can get it) and drink when they are thirsty. This majority is given to labelling all the others as faddists, and indeed there does not seem to be a very noticeable difference in health between any of these groups. No wonder then, that the average person is apt to be a little sceptical when he is told that health depends on diet.

What then should be the reply to the would-be seeker after health who asks 'What shall I eat that I may be whole?'

For an answer let us go to those people from whom Dr. Wrench, in his student days, felt instinctively that such knowledge should be sought, namely the ultra-healthy. Not the occasional individual of whom one says that he is 'abnormally healthy' (a revealing adverb) but to whole groups of people to whom a state of full health is normal.

Five such groups exist, or have existed, about which a good deal of statistical data is available. We will examine these in turn, noting how they live and what they eat, and see if we can discover among them a common factor of which it is permissible to say-here lies the secret of health.

We will take first the people of Hunza, a small native state in the extreme northernmost part of India attached to the Gilgit Agency. The origin of these people is somewhat of a mystery. Both in physical characteristics and language they differ from their neighbours, and indeed from all the other peoples of the Indian sub-continent. Only one thing seems certain, that they have inhabited their valley since the extremely distant past. The massive stone walls, the building of which must have preceded their admirable terraced agriculture, have a parallel only in the masonry left by the Peruvian civilization which preceded the Inca conquest.

The Hunza valley is a gorge running east and west cleft in a towering mountain range. It is arid in summer and bitterly cold in winter, but owing to the system of irrigation, it is extremely fertile and an immense variety of fruits and vegetables are cultivated by these industrious people.

Something of their superb health and stamina has already been indicated in Chapter II. All travellers passing through their valley speak of their outstanding physique, courage and good humour. McCarrison, who for some time was Medical Officer to the Gilgit Agency, has said of them:

'These people are unsurpassed by any Indian race in perfection of physique. They are long lived, vigorous in youth and age, capable of great endurance and enjoy a remarkable freedom from disease in general.

'During the period of my association with these people I never saw a case of asthenic dyspepsia, of gastric or duodenal ulcer, of appendicitis, of mucous colitis, of cancer. . . .

'Among these people the "abdomen over-sensitive" to nerve impressions, to fatigue, anxiety, or cold was unknown. The consciousness of the existence of this part of their anatomy was, as a rule, related solely to the feeling of hunger. Indeed, their buoyant abdominal health has, since my return to the west, provided a remarkable contrast with the dyspeptic and colonic lamentations of our highly civilized communities. They are admirable cultivators, 'far famed as such and "conspicuously ahead of all their neighbours in brain and sinew" stated Shomberg Their big irrigation conduit, the Berber, is "famous everywhere in Central Asia. . . ."

'Amongst the peoples of the Agency not only are they "as tillers of the soil quite in a class apart, they alone--and this always strikes me as truly remarkable--are good craftsmen." As carpenters and masons, as gunsmiths, ironworkers, or even as goldsmiths; as engineers for roads, bridges or canals, the Hunza men are outstanding.'

The Hunza are favoured in their fertile valley, but their perfect health cannot be put down to the locality in which they live, for next door to them is another, and equally fertile, valley, also running east and west and separated from Hunza only by a 20,000-foot mountain wall. In this valley live the Ishkomanis. These people, 'though living under apparently like conditions to their neighbours, were poor, undersized, undernourished creatures. There was plenty of land and water, but the Ishkomanis were too indolent to cultivate it with thoroughness; and the possibility of bad harvests was not enough to overcome their sloth. . . . "They had no masons or carpenters or craftsmen in their country. Many of them showed signs of disease."'

We can thus rule out climate as the secret of the Hunza health. Now, let us look at their mode of life and their diet. For ten months of the year they can be said to live in the open-air, for men, women, and children work in the fields. They remain mainly indoors during the period of severe winter storms, but their houses are better, and better ventilated than those of their neighbours, their sanitation is also better and follows the 'immemorial custom of the Far East'. Unusual care is also taken to protect their drinking water by storing it in separate covered cisterns.

Their diet is a very varied one. It consists of: 'Wheat, barley, buckwheat, and small grains; leafy green vegetables; potatoes (introduced half a century ago), other root vegetables; peas and beans, gram or chick pea, and other pulses; fresh milk and buttermilk or lassi; clarified butter and cheese; fruit, chiefly apricots and mulberries, fresh and sun-dried; meat on rare occasions; and sometimes wine made from grapes. Their children are breast fed up to three years, it being considered unjust to the living child for its lactation to be interrupted by a maternal pregnancy.

'The Hunza do not take tea, rice, sugar or eggs. Chickens in a confined area destroy crops and are not kept.'

Except for the wider range of small grains and the very occasional meat, this closely resembles any European lacto-vegetarian diet, and, at first sight, seems to support the view so widely held by nutrition experts, McCarrison among them, that of all diets the lacto-vegetarian is the healthiest. That it is a good diet is incontestable; it will, however, presently be shown that there are other peoples whose health and stamina is equal to that of the Hunza whose diet is the very opposite of theirs.

The Hunza foods then are not unlike our own, but there are important differences in the normal methods of preparation and cooking. Both we and the Hunza are great bread-eaters, and both prefer wheat bread, but the Hunza wheat is eaten freshly ground, and the unleavened bread made with it invariably contains the whole of the grain, with its vital germ and its protective skin, both of which are removed in the process of milling white flour.

Dr. Wrench, writing on the properties of skin in general, points out that skin does not protect only in a mechanical way as a mere covering, but in a living way. All skins 'can regrow themselves if injured, and beneath and within them they stork substances upon which they can call to strengthen their efforts.' The value of bran, the skin of wheat, is well known to all stock feeders. All carnivorous animals relish the skins of their prey. The Greenlanders, Wrench points out, eat the skin of the narwhal: 'The Chinese and other peoples also eat the skins of animals and birds. Everything living has a skin of some sort to protect it. It protects it by its extra toughness, but also if microbes and other minute enemies do attack, it is there on the frontier that the battle is waged. In and near the skin are marshalled the protective forces. Any creature that eats the skin of vegetable, fruit, or animal, also eats these protective materials marshalled on the frontier, and may benefit in its own protection thereby. Whether such a pretty hypothesis is true or not, there are suggestion s that skins possess a peculiar value. . . . The skin and adjacent part of the potato is the best part, as the Irish know. So also is it the case with the carrot, and, it is said, with young marrows, cucumbers, gherkins, artichokes, radishes, and celery. There is, therefore, a little evidence for the hypothesis.'

A fondness for skin is an outstanding feature of the Hunza, they do not peel their vegetables, or wash and soak them to the extent we do. Vegetables play a great part in their diet and are very commonly eaten raw. 'They are fond of raw green corn, young leaves, carrots, turnips, and, as it were to exaggerate their veneration for freshness, they sprout their pulses and eat them and their first green. This eating of sprouting pulse or gram is widespread in northern India, and undoubtedly within it there is a health which there is not in the pulse itself.'

Fuel in Hunza is scarce, and when they do cook their vegetables they are boiled in covered pots as is the usual habit in this country.

'But the process is more comparable to our way of steaming and cooking in their own juice. Very little water is added. When this has been used up more is added. The water in which the vegetables are cooked is drunk either with the vegetables or later. The point is that it is part of the food. It is not thrown away.'

This taking of vegetable water is obviously sensible, for many of the valuable mineral salts which vegetables contain pass into the water in which they are cooked, particularly if the vegetables are peeled before cooking. 'There is abundant evidence from the scientists of the loss that occurs through the throwing away of vegetable water of phosphorus, calcium, iron, iodine, sulphur, etc. Quite a considerable proportion of the pharmacopoeia seems to have arisen owing to this waste. Quite a considerable number of the doctors' prescriptions and patent medicines may be due to the need to replace the salts of the food in those who suffer from this loss. The similarity of the medicines and the lost salts is too close for one not to be profoundly suspicious that the methods of cooking cause or contribute to the subsequent need of the medicines.'

The Hunza drink milk in considerable quantity, they drink it whole and they boil the fat from it to form clarified butter or ghee, which they spread on their bread and also use for cooking. They drink the buttermilk which remains, and both this and their whole milk they preserve in hot weather by souring. Meat is a 'rare pleasure', most of their livestock being dairy animals. They rarely eat meat more than once in ten days, and often only about once a month. When they do, they eat all that is edible in the carcass and stew it together with their vegetables and pounded wheat. But ranking above all the foregoing in the Hunza diet is fruit. "'The Hunza are great fruit eaters, especially of apricots and mulberries. They use apricots and mulberries in both the fresh and dry state, drying sufficient of their rich harvest of them for use throughout the autumn and winter months." (McCarrison.) They eat the fruit fresh in season, cracking the stones and eating the kernels as well. Otherwise they take them, particularly sun-dried apricots, and eat them as they are, or rub them in water to form a thick liquid called *chamus.* Dried mulberries they put into cakes as we do sultanas. They do not cook their fruits. "Fruit is really the Hunza staple. It is eaten with bread, far more so than vegetables, as it is more abundant."' (Schomberg.) ...... Even the animals," said Durand, "take the fruit diet, and you see donkeys, cows and goats eating the fallen mulberries. The very dogs feed on them, and our fox-terriers took to the fruit regimen most kindly and became quite connoisseurs."' They ferment some of their fruit juices and on festive occasions drink their own home-made wine.

So far the main differences between the Hunza diet and our own seems to be that the Hunza foods are all natural foods, they are eaten fresher than ours, and they are consumed whole, but there is one more difference, the most fundamental of all, and this lies in the way in which these foods are grown.

In their system of agriculture which has been continued 'century after century' the chief factors in their plant food have been two.

'Firstly, there is the continuous slight renewal of the soil by a sprinkling of the black glacier-ground sand, which is brought to the fields by the aqueducts.

'Secondly, there is the direct preparation by man of food for the plants, given in the form of manure.

'The Hunza, in their manuring, use everything that they can return to the soil. They carefully collect the cattle manure and store it in the byres. They collect all vegetable parts and pieces that will not serve as food to either man or beast, including such fallen leaves as the cattle will not eat, and mix them with the dung and urine in the byres. They use the human sewage after keeping it for six months. They take silt from special recesses built in their irrigating channels. They collect the ashes of their fires. All these they mix together and make into a compost. They also spread alkaline earth from the hills on their vegetable fields on days when the fields are watered.'

O. F. Cook of the Bureau of Plant Industry of the U.S.A. Department of Agriculture has written: 'Agriculture is not a lost art, but it must be reckoned as one of those which reached a remarkable development in the remote past and afterwards declined.' As an example he cites the system of the ancient Peruvians which enabled them to support large populations in places 'where modern farmers would be helpless'. ('Staircase Farms of the Ancients', *National Geographic Magazine.* May 1916.)

Travellers who have visited both Peru and the North West Indian Provinces have been struck by the resemblance between the stone aqueducts and mammoth walls that support the terraced fields of both areas. Describing those of Hunza the late Lord Conway wrote: 'The path that leads up to Baltit, the capital of Hunza, is bordered on either side by a wall of dry cyclopean masonry the undressed component parts of which are very large and excellently fitted together . . . a monumental piece of simple engineering . . . the valley between the cliffs and the edge of the river's gorge is covered with terraced fields. . . . The cultivated area of the oasis is some five square miles in extent. When it is remembered that the individual fields average as many as twenty to the acre, it will be seen what a stupendous mass of work was involved in the building of these walls and the collection of earth to fill them. The walls have every appearance of great antiquity, and alone suffice to prove the long existence in this remote valley of an organized and industrious community. . . .

'To build these fields was the smaller part of the difficulties that husbandmen had to face in Hunza. The fields also had to be irrigated. For this purpose there was but one perennial supply of water-the torrent from the Ultar glacier. The snout of that glacier, as has been stated, lies deep in a rock-bound gorge, whose sides are for a space perpendicular cliffs. The torrent had to be tapped, and a canal of sufficient volume to irrigate so large an area had to be carried across the face of one of these precipices. The Alps contain no Wasserleitung which for volume and boldness of position can be compared to the Hunza canal. It is a wonderful work for such toolless people as the Hunzakats to have accomplished, and it must have been done many centuries ago and maintained ever since, for it is the life-blood of the valley.'

Thus it can be seen that the Hunza appear to form a direct link between the present day and that 'remote past' in which agriculture reached such a 'remarkable development'. They are a people perhaps as ancient as the Incas, but who, unlike the Incas, have survived, and in their survival have preserved their ancient lore, and in the preservation of that lore have preserved the wholeness of their health and that of their crops and livestock, which Dr. Wrench tells us is on a par with their own.

The blight which Western civilization usually casts on such people, has so far escaped them. Whether it will continue to do so is another matter. Since they have come under British suzerainty their population has increased from about six thousand to fourteen thousand, and this has resulted in a shortage of food in the pre-harvest period

'Colonel D. L. Lorimer, who was Political Agent at Gilgit, 1920-4, and revisited the Hunza and lived amongst them at Alibad, 1933-4, four miles from the capital, Baltit, told me that not only did they seem smaller to him at his second visit, but that the children appeared undernourished for the weeks preceding the first summer harvests half-way through June; and, moreover, that the children suffered at that time of the year from impetigo, or sores of the skin, all of which vanished when the more abundant food came.'

A sign, incidentally, that it is not by virtue of their race, or habitat, or housing, that they are normally immune from bodily ailments.

We will now go from Latitude 37 to the northern and Arctic regions from the lacto-vegetarian diet of the Hunza to the carcass diet of the islanders of Faroe, Iceland, and Greenland. Early records of these peoples show them to have been every whit as healthy as the Hunza, yet these people are, or were, almost entirely carnivorous.

'These Danish possessions are three isolated lands from which no Western civilized person would expect to glean wisdom. But, as we have already seen in the case of food and health, isolation locks up the most valuable secrets. The peoples of these three lands, living either near or actually within the Arctic Circle, offer in three degrees, from Faroe to Greenland, an increasingly animal-fish-bird diet. It must not be called a meat diet; that is inaccurate as will be seen. It was largely a diet from the sea, and with the great health of the sea, a "soil" outside the realms of terrestrial man.

'The diet of the Faroe Islanders, when they were more isolated than now, was given in a book published by the Edinburgh Cabinet Library in 1840. It was mainly a whole carcass diet of animal, bird and fish. The islanders ate not merely meat, but everything that could be eaten. There was no such thing as offal. They also made the carcasses gamey by hanging for weeks and even months. In addition to their whole carcass food they had barley meal, unleavened barley bread, a few vegetables such as cabbages, parsnips and carrots.

'They drank milk, beer, and, on festive occasions, brandy. But the main food was animal, bird and fish.

'The islanders numbered a few thousands, were of the same origin as the Icelanders, and were, "in general, remarkably intelligent. They are extremely healthy, and live to a great age, and an old man of ninety-three years lately rowed the governor's boat nearly ten miles". One danger they incurred was an epidemic catarrhal fever, such as we call influenza, which "prevails after the arrival of the ships from Denmark in the spring", after the winter's scarcity. It spreads rapidly and was sometimes fatal. Otherwise, "but few diseases are prevalent amongst them".

'The inhabitants of Iceland offer a similar and even more interesting picture of carcass diet. McCollum and Simmonds, in *The Newer Knowledge of Nutrition* (1929) summarize the chief facts. "This island was settled in the ninth century by colonists from Ireland and Scandinavia, who took with them cattle, sheep and horses. Their diet was practically carnivorous in nature for several hundred years. Martin Behaim (quoted by Burton), writing of Iceland about 1500, stated, 'In Iceland are found men of eighty years who have never tasted bread. In this country no corn is grown, and in lieu, fish is eaten.'"

'Burton, quoting Pearse, states that rickets and caries of the teeth were almost unknown in Iceland in earlier times. . . . The health conditions were good and dental caries was unknown until after 1850. Stefansson exhumed ninety-six skulls from a cemetery dating from the ninth to the thirteenth centuries and presented them to Harvard University. They have been described by Hooton (1918), who found no evidence of caries in any of them. There were but three to four defective teeth in the entire series, and these had suffered mechanical injury. During the last half century caries has steadily increased in Iceland.

'Modern Iceland had not the isolation of the period which Burton described. There had been a great advance in civilization and population. Fifty per cent of the people now live in towns or trading stations. There are four agricultural schools. Potatoes, turnips, and rhubarb are cultivated. Iceland imports the trade foods, such as flour, sugar, preserved fruits and tinned foods. Caries has become common, as have many other ailments.'

That this regrettable decline in health cannot be attributed to the change from country to town life, is proved by a remarkable experiment carried out in Denmark itself during the last war.

'The blockade, following the entry of the U.S.A. into the war, put the Danes in a very serious position. Professor Mikkel Hindhede, Superintendent of the State Institute of Food Research, was made Food Adviser to the Danish Government to deal with it.

'The problem that faced him was this; Denmark had a population of 3,500,000 human beings and 5,000,000 domestic animals. She was accustomed to import grains from the United States for both. There was now a shortage of grain foods.

'In this crisis Hindhede decided that a drastic reduction in the livestock must be made. So some four-fifths of the pigs were killed and about one-sixth of the cattle. Their grain food was given to the Danes, and it was given . . . as wholemeal bread with the extra coarse bran that is not put into ordinary wholemeal bread, incorporated.

'In addition to this bread, or Kleiebrot, which was made official for the whole country, the Danes ate porridge, green vegetables, potatoes and other root vegetables, milk, butter, and fruit. No grain or potatoes were allowed for the distillation of spirits, so there were no spirits. Half the previous quantity of beer was permitted.

'As some pigs were left, the people on the farms got meat; the people in the cities--40 per cent of the population--got very little meat. Only the rich could afford beef.

'The food regulations were begun in March 1917 and were made stringent from October 1917 to October 1918.

'The result of this enforced national diet was a remarkable lowering of the death-rate. The death-rate, which had been 12.5 in 1914, now fell to 10.4 per thousand, "which is the lowest mortality figure that has been registered in any European country at any time." (Hindhede.)

'Hindhede puts this impressive result in another way. Taking the average from 1900 to 1916 as 160, in the October to October year it was 66. Even in men over sixty-five the figure fell to 76.

'Hindhede attributes this extraordinarily rapid and marked change to two things: (1) less meat, (2) less alcohol. He regards the bran as having largely filled the gap of the scanty or absent meat, bran having a good proportion of vegetable meat or protein. He regards the experiment as a triumph for his previous teaching. "The reader knows", he writes in the *Deutsche Medizinische Wochenschrift* of March 1920, "how sharply I have emphasized the advantages of a lacto-vegetarian diet. I am not in principle a vegetarian, but I believe I have shown that a diet containing a large amount of meat and eggs is dangerous to health."'

And yet we have only to turn to another Danish possession (ironically enough) to find a refutation of this rather narrow view.

'The north-west coast of Greenland, where the Polar Eskimos live, is within the Arctic Circle. It is the most isolated and the least affected by civilization of these three possessions of Denmark.

'Some attempts at gardening have been introduced by the Danes, but previously the only vegetable food the Eskimos got was from the profuse but, in species, limited vegetation of the Arctic summer. Otherwise they lived mainly on sea animals and sea birds. There was no offal. They ate everything that could be eaten. When it was frozen they often ate it raw. The thick, heavy skin of the narwhal is particularly favoured. The millions of sea birds which visit their coast supply a winter store of meat and eggs.

'The Eskimos are also exceptionally healthy. "The fact that the Eskimos of this polar tribe have such excellent physique, hair, and teeth, and such superb health without any trace of scurvy, rickets, or other evidence of malnutrition," write McCollum and Simmonds, "is interesting in the light of their restricted and simple diet."

'It is also interesting as a counterweight to Hindhede and other nutritionists who plump for the excellent lacto-vegetarian diet. There are other excellent diets, and the whole-carcass one of the polar Eskimos is one of them.'

From the far north our next jump is to the Island of Tristan da Cunha in the South Atlantic. 'The people of this island are people of our own race living on the products of sea and soil, most of them have perfect teeth which last them all their lives. . . .

'Mr. James R. A. Moore, L.D.S., R.C.S. (Eng.), visited the island in 1932 and again in 1937. In 1932 he examined 156 persons and 183 in 1937. Of the 3,181 permanent teeth in the former year, there were 74 carious and of the 3906 in the latter year there were 179 carious.

'He speaks of the physique of the people as being good. They are well set up, clean and well nourished. The children are breast fed and are not weaned until at least one year old. Fish and potatoes are the staple diet, meat occasionally, milk and butter sufficient. Eggs form a big item of the island diet and are mainly Mollyhawk and penguin. Vegetables are not plentiful, but beetroot, lettuce, beans and onions are now being grown. Imported flour and sugar are regarded as luxuries, but they have been brought in to a greater extent latterly, which may account for the tendency of the teeth to deteriorate.

'The fat in adequate amount is provided by rendering down the carcasses of young Mollyhawks and petrels and is used extensively for frying. Sea water is evaporated to provide salt." (Refer to the Medical Testament.)

It will be seen that the people of this island, also noted for their sound health, (For further information on health conditions in Tristan da Cunha see *Tristan da Cunha,* by Erling Christophersen, English translation published by Cassell & Co., 1940.) have a more varied diet than that of the Eskimo, though like them much of it is derived from the sea. Eggs form a large part of their diet-one of the items condemned by Hindhede. It is worth noting that a marked difference exists between the methods of cooking adopted by the Tristan Islanders and the Hunza, for whereas the latter cook everything together in one pot, the people of Tristan never partake of more than one kind of food at the same time.

For our fourth example of a (once) superlatively healthy race, we must go to the North American Indian of the pioneer days. Observation of these people since they have been forced to live in reservations has been very carefully recorded.

'All who observed the Indians in their primitive state agree that most of them were exceptional specimens of physical development. With few exceptions, however, during two generations, they have deteriorated physically. The reason for this is apparently brought to light by a consideration of the kind of food to which they have restricted themselves since they have lived on reservations.

'There is no group of people with a higher incidence of tuberculosis than the non-citizen Indian. As wards of the Government they have been provided with money and land, but have in general shown little interest in agriculture. They have lived in idleness, and have derived their food supplies from the agency stores. In addition to muscle cuts of meat they have, therefore, taken large amounts of milled cereal products, syrup, molasses, sugar and canned foods, such as peas, com, and tomatoes. In other words, they have come to subsist essentially upon a milled cereal, sugar, tuber, and meat diet. On such a regimen their teeth have rapidly become inferior and badly decayed. They suffer much from rheumatism and other troubles which result from local infections. Faulty dietary habits are in great measure to be incriminated for their susceptibility to tuberculosis.

'Other classes of Indians, who have become successful farmers, have not deteriorated as a result of contact with civilization, except in so far as they have suffered from alcohol and venereal infections. The noncitizen Indian has suffered, not because of contact with civilization, but because he has been forced into dietary habits which are faulty.' (McCollum and Simmonds.)

In the days of their prime these people subsisted mainly on the wild game of virgin forest and prairie, regions in which, as was pointed out in a previous chapter, the law of return operated fully.

For the last example I go back to the continent of Asia, to the people of rural China. Their diet is nearer to that of the Hunza than to any of the other examples we have looked at. Fruit, vegetables and sprouted grain are staples of both diets, but unlike the Hunza the principal cereal of the Chinese is rice, not wheat, and they also eat meat, birds, fish and eggs. They are in addition, as is well known, great tea drinkers. In common with the other four groups they eat the whole carcass and the whole grain or vegetable. In the matter of preparation they resemble the Hunza in that everything is eaten together. But are we justified in claiming that they are healthy?

Sooner or later all advocates of organic farming cite the Chinese, going so far as to call them the Fathers of good husbandry. Their authority for doing so is almost always Professor King's famous book, *Farmers of Forty Centuries.* The critics of the 'organic school', however, challenge the accuracy of King's report. They say that he was only in the country for a few weeks, that the Chinese people as a whole have an abnormally high death rate, and that the whole country is riddled with disease, most of which is sewage borne because the peasants fail to compost their human wastes.

I have made great efforts to check these two opposing views. The truth seems to lie in the statement from Lord Northbourne's *Look to the Land,* already quoted in the first chapter of this book, that 'China presents remarkable contrasts between the best and the worst'. It is a vast country. Undoubtedly conditions are very bad indeed in some areas, particularly in the overcrowded cities, both as regards health and sewage disposal. But there seems equally little doubt that in certain rural areas composting of a very high order, amounting to a fine art, has been practised for centuries. But, however the overall picture should be painted, one fact seems indisputable, namely, that through the operation of the closed cycle (i.e. without the importation of chemical fertilizers) the soil of China has--despite periodic floods and famines--supported a huge population and a high culture for a period of 4,000 years. For this reason, I feel quite justified, after having drawn attention to the other side of the picture, in once more quoting King. He was, after all, Chief of the Division of Soil Management in the United States Department of Agriculture, and as such a qualified observer, recording facts as he found them. The references to the Medical Testament contain an admirable summary of King's findings, and it is from that document that the following account is taken.

'King frequently inserts into his pages the cheerful, vigorous and healthy appearance of the Chinese lower classes, the Shanghai coolies, "fully the equal of large Americans in frame, but without surplus flesh"; "their great endurance", "both sexes are agile, wiry, and strong" (Hong Kong) ; "lithe, sinewy forms, bright eyes and cheerful faces, particularly among the women, young and old" (Canton) ; "everywhere we went in China the labouring people appeared healthy and contented, and showed clearly that they were well-nourished". Cheerfulness is, indeed, common to those peasantries who follow the old agricultural ways.'

'The average of seven Chinese holdings . . . indicates a maintenance capacity of 1,783 people, 212 cattle or donkeys and 399 swine--1,995 consumers and 399 rough food transformers per square mile of farmland. These statements for China represent strictly rural populations. The rural population of the U.S.A. in 1900 was placed at 61 per square mile of improved farm land and there were 30 horses and mules. . . .'

'They (the Chinese) have long realized that much time is required to transform organic matter into forms available for plant food, and, although they are the heaviest users in the world, the largest portion of this organic matter is predigested with soil or subsoil before it is applied to the fields. This is at an enormous cost of human time and labour, but it practically lengthens their growing season and enables them to adopt a system of multiple cropping which would not otherwise be possible. By planting in hills and rows with intertillage it is very common to see three crops growing upon the same field at one time, but in different stages of maturity-one nearly ready to harvest, one just coming up, and the third at the stage when it is drawing most heavily on the soil. . . .'

This disposes of the theory that increased production and heavy cropping have been responsible in this country for our diseases in crops. The Chinese have been cropping in this way for forty centuries.

'The Chinese manure or compost is made of everything that can be collected which once got its life from the soil, directly or indirectly. They are mixed together until they form a black friable substance which is readily spread upon the fields. King describes a number of different processes he saw in different parts of China. One he describes as being carried out in compost pits at the edge of a canal, a process entailing "tremendous labour of body and amount of forethought". For months before his visit men had brought waste from the stables of Shanghai, a distance of fifteen miles by water. This they had deposited upon the canal bank between layers of thin mud dipped from the canal, corresponding to silt collected in and taken from the recesses in the Hunza aqueducts, and left to ferment. The eight men at King's visit had nearly filled the compost pit with this stable refuse and canal silt. The pit was in a field in which clover, with its peculiar power of taking nitrogen from the air, was in blossom. This was to be cut and piled to a height of five to eight feet upon the compost in the pit, and also saturated layer by layer with canal mud. It would then be allowed to ferment twenty to thirty days, until the juices set free had been absorbed by the winter compost beneath and until the time that the adjacent land had been made ready for the coming crop. The compost would then be distributed by the men over the field.

'At another time he saw a compost pit within a village in which had been placed all the manure and waste of the households and streets, all stubble and waste roughage of the fields, all ashes not to be applied directly, mixed up with some soil. Sufficient water was added to keep the contents of the pit saturated and to promote their fermentation. All fibres of organic material have to be broken down, which may require working and reworking, with frequent additions of water and stirring for aeration. Finally the mixture becomes a rich complete fertilizer. It is then allowed to dry and is finely pulverized before it is spread upon the land.

'Every foot of land, says King, is made to provide food, fuel, or fabric. "The wastes of the body, of fuel, and fabric, are taken back to the field; before doing so they are housed against waste from weather, intelligently compounded and patiently worked at through one, three or even six months, in order to bring them into the most efficient form to serve as manure for the soil or as feed for the crop."'

These then are the five peoples (It appears that to this list should be added the people of Prince Edward Island. See report by Dr. Enid Charles in the *Canadian Journal of Economics and Political Science,* vol viii, 1942.) which either still enjoy an exceptional measure of health, or else until very recently have done so. What have they in common?

Not race, for the groups include white, brown, red, and yellow races.

Not climate--there could hardly be greater contrasts than between the plains and hills of rural China or the prairies of North America and the precipitous mountain crags of the northern provinces of India, or than between the frozen north and the luxuriant warmth of Tristan da Cunha.

Not diet--in the ordinary sense--for these range from the lactovegetarian diet of the Hunza to the almost purely carnivorous diet of the Eskimo, with almost every variant in between.

Not methods of preparing their food either, for though there are certain resemblances--as between Hunza and Chinese for example--no methods are common to all five.

In fact it seems clear that it is not in *kind* at all that we must look for our common factor, but in *quality.*

All five groups have good air to breathe, but that cannot by itself be the secret of their health, or our own hill and country dwellers would have health to compare with theirs, which, unfortunately, they have not.

The only discernible common factor, other than good air, seems to be that the diets of all five groups are 'whole' diets in the full sense of the word. That is to say: (*a*) every edible part contained in the diet is consumed. (*b*) In every case the foods are grown by a system of returning all the wastes of the entire community to the soil in which they are produced. For the sea too is a 'soil' in this sense, supporting its teeming population by means of the rule of return--the everlasting cycle of life and decay. (*c*) All the foods are natural unprocessed foods. (*d*) The diets start before life begins; the parent is as healthy as the child.

There is a complete and continuous transference of health from a fertile soil, through plant and/or animal to man, and back to the soil again. The whole carcass, the whole grain, the whole fruit or vegetable, these things fresh from their source, and that source a fertile soil. Herein appears to he the secret. If this be true, then the answer to our question, put at the beginning of this chapter, would appear to be that *any* diet is a health-promoting diet so long as it conforms to these three rules, and the first of these is a fertile soil.

'The importance of the method of culture of food is primary, radical, and fundamental in the matter of health. It exceeds all other aspects of nutrition--if, that is, one separates any aspect of what is a whole.'

In the case of diets based on agriculture, such a view brings us back again to humus farming.

CHAPTER VIII
THE HAUGHLEY RESEARCH TRUST AND THE SOIL ASSOCIATION

'My faith not only dares the searching light of reason, but demands it.'
Coventry Patmore

The evidence laid before you in the preceding chapters presents the case for a view on health that can be summed up under five propositions.

(1) The primary factor in health (or the lack of it) is nutrition.

(2) Fresh unprocessed natural whole foods (such as wholewheat bread, and raw vegetables and salads) have a greater nutritive value than the same foods when stale, or from which vital parts have been removed by processing, or have been destroyed by faulty preparation.

(3) Fresh foods are more health-promoting than preserved foods (dried, canned, or bottled).

(4) The nutritive value of food is vitally affected by the way in which it is grown.

(5) An essential link in the nutrition cycle is provided by the activities of soil fungi, and for this and other reasons the biological aspects of soil fertility are more important than the chemical.

My own view is that of these five premises, the first two have been pretty conclusively proved, but that the last three have still to be fully established. Nevertheless while admitting that critical scientific proof is at present lacking, I maintain that the indications in support of them are so strong, that it has become a matter of the utmost national urgency to submit them, without delay, to a final and conclusive test.

For many years now the Government of the day has been constantly pressed by those in high places who support the biological school of thought to establish such a test, but so far without result. It is notable that opposition to a long term experiment designed to determine the issue comes from the orthodox agricultural chemists and not from the humus enthusiasts who are willing and eager to put their theories to the proof. The inference is obvious--either the chemists are, at heart, not sure of their ground, or else, suspecting that they are wrong, they are fighting to preserve their vested interests at the possible expense of national health. If it had not been for this obstruction, this vital question would surely have been answered long since. It may be asked, why have not some of the humus enthusiasts carried out such a test on their own initiative. One reason is, that few have been in a financial position to do so, all large scale experimental work is expensive, but I believe there is a deeper and more fundamental reason; a psychological one. In attempting to explain it, I must ask you to make allowances for the error inherent in all generalizations.

Broadly speaking then, the mentality of the large scale users of chemical fertilizers is, I think, in the main a commercial mentality; the mentality that measures values in terms of money and is out for quick returns, whereas the 'composters', inevitably made alive all the time to the biological factors of soil, develop different standards. They are very much aware of their responsibility; their outlook is one of service to the soil, not exploitation; farming to them is a vocation, not a trade. When they become convinced that their biological approach to the soil is right in the interests of the soil itself, any soil treatment which runs counter to this, becomes such heresy to them that they cease to be capable of a detached and purely scientific atitude to the problems involved.

I am aware of this danger in myself, but I have been brought up with a sufficiently scientific background to be able to control it, in the interests of truth. For it is quite clear to me that if humus is indeed the basis of health, we shall get no further towards achieving health until evidence is provided of so conclusive a nature that scientists are ready to accept it as proof. Scientists are always slow to accept any new principle because scepticism is a necessary part of their make up. Without it they would not be scientists. This scepticism only ceases to be a virtue when suspicion of any new theory is carried to the length of obstructing work designed to provide proof. Unfortunately, the history of new scientific discoveries is interwoven with just such obstruction from the very people whom one would expect to welcome investigation.

A good example of this is provided by the history of Pasteur and Lister. The Cheshire doctors provide a notable exception to it.

Thus it seems to me that the initiative in this, as in so many other new developments of science or of social reforms, must be taken by private enterprise. Governments in this country follow but seldom lead new movements. If all enterprise in our past history had waited on Governments, there would be no such thing to-day as the British Commonwealth of Nations, and probably little also in the way of health services.

'Unquestionably', state the compilers of the P.E.P. report, 'many of the greatest achievements of the British health services up to the present time have been due to voluntary initiative.' They go on to say that 'The scope for work by voluntary bodies in the health services appears to fall into five classes: (*a*) work in which freedom of opinion in teaching or research is absolutely vital; (*b*) work which is of a controversial nature; (*c*) work which is of a pioneering character and contains an element of risk; (*d*) other "charitable" work which no public body thinks part of its duty although its value is generally recognized; (*e*) work where the disease or health problems involved affect the social life of the individual and there is scope for personal influence or example.' (P.E.P. Report on British Health Services,1936.)

In a democracy, then, it seems that pioneering, even in matters of health, must be the function of the individual. Luckily great causes usually produce their pioneers. First must come those who make the initial discoveries, and after them men of vision, prepared, in the face of all difficulties, to prove that the discoveries are worth official recognition. As an example, one might cite Columbus, who discovered America, and Raleigh, who founded the first English colony.

The new world (if such indeed it prove to be) which is appearing on the horizon as a result of the probable relationship between humus and health, has not lacked its Columbus, and it has had at least one Raleigh too, in the person of the late Alice Debenham. The tragedy is, that she died at the very outset of her great purpose, leaving to others the task of bringing to fruition the seed she sowed.

A practical farmer, trained in science and medicine, and during the latter years of her life an invalid, Alice Debenham saw very clearly the potential importance of the evidence concerning soil fertility and health. She saw equally clearly that this scattered evidence must be collected and reproduced under controlled conditions if it were to convince the scientific world, and that unless science is convinced, Governments will not act.

Outstandingly public spirited, she founded a Research Trust to carry out this work. As custodians of it, she appointed the East Suffolk County Council. By this means the Trust immediately gained an official status that a purely private body would not have achieved, while, at the same time, the terms of the Trust gave it a much greater freedom of action than would have been possible to a Government-run concern, even including a provision to delegate the work should that seem desirable. In 1939, she presented, to this Trust, under a deed of gift, about eighty acres of farm land together with a limited number of farm buildings and an admirably modernized farm-house. This eighty acres marches with a 150-acre holding which I had been farming since 1919 and it was agreed between us that this land should be leased or sold to the Trust so that the total experimental area should not be less than two hundred acres. (See Fig. 5.) This was considered to be the minimum acreage needed for carrying out the experiment for which the Trust was chiefly formed, namely to divide a farm into three sections for the purpose of making a comparison from the *health point of view* of three different systems of farming based on three different conceptions of the true nature of nutrition. The first system is based on the ecological conception of nutrition as a cycle--a flow of materials from the soil and back to the soil--in which a vigorous soil population forms an essential sector, being the agency through which humus feeds the plant *indirectly.* The second system is based on the belief that all food materials needed by plants can be provided in the form of soluble chemical nutrients, provided physical conditions are favourable to water retention. The third system is based on the now orthodox view that all farmyard manure, and other humus-forming materials available, should be returned to the soil, but that these must be supplemented by soluble chemical fertilizers because farmyard manure or compost (except in such heavy dressings as to be out of the question practically) are deficient in essential plant food.

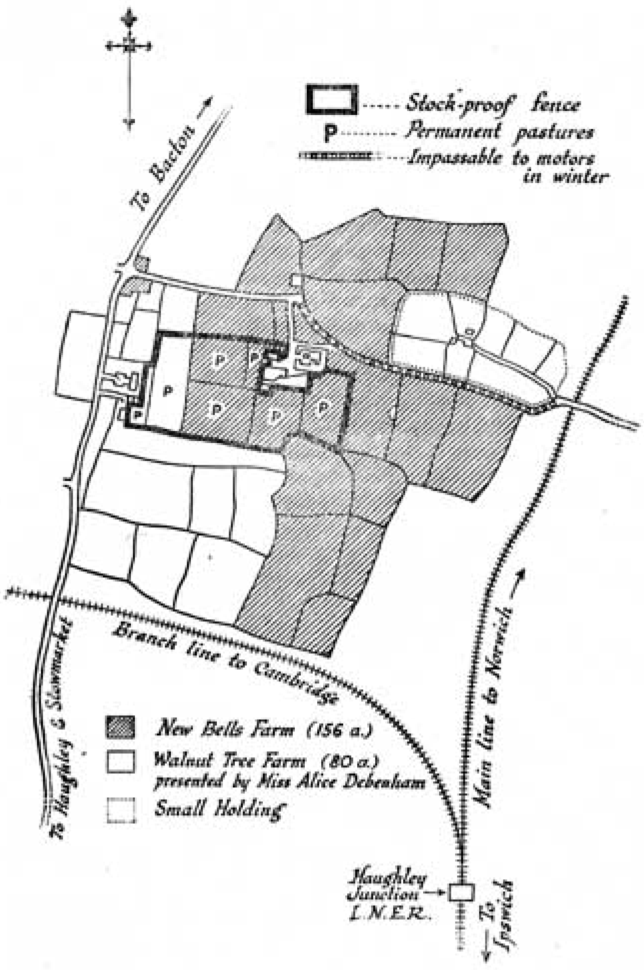


FIGURE 5

Miss Debenham was very vividly aware of the urgent need for a long term comparative test of these three theories, on a field scale and under controlled conditions, and she was partly prompted to her generous gift because of the extreme suitability, for this experiment, of the proposed site at Haughley. Firstly the fields are all small, averaging 6 acres or thereabouts, and are all divided by deep ditches; this enables each plot to be one whole self-contained field isolated from the neighbouring plots so far as the drainage system is concerned. At the same time the small fields make it possible to carry out the whole experiment within a fairly small total area (236 acres). Secondly the land is all flat, so that differences in aspect hardly arise. Thirdly, the character of the soil is fairly uniform--clay loam, on mixed clay and sand sub-soil, overlying chalk. Such variations as do occur are distributed in such a way that all soil types can be represented on all three sections. (See Fig. 6.)

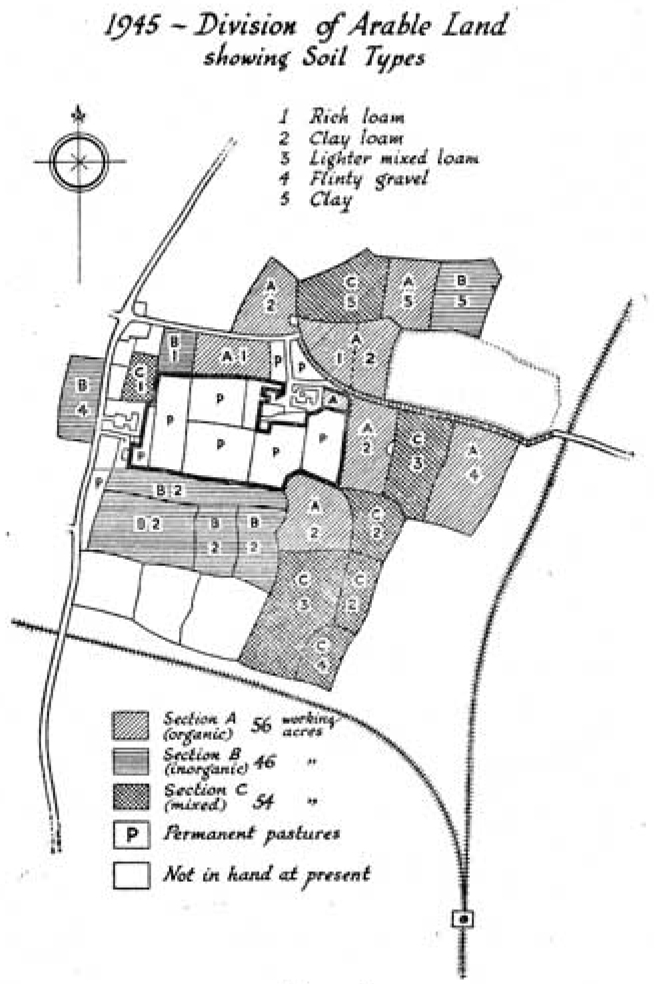


FIGURE 6

In 1940 the preparatory work was begun. The gradual development of the programme through its preliminary stages has been fully described in earlier editions of this book. I do not propose to recapitulate them in detail here since my object is to bring the story up to date. In order to do so I must make a slight digression to introduce the Soil Association.

In 1943, while the work of the Trust was gradually developing, the first edition of this book was published. The many hundreds of letters which I received in consequence, made it very clear indeed that a deep and ever-growing conviction was taking place among all sections of the community that the right approach to health is the positive one of promoting vitality rather than the negative one of preventing disease. These letters also made me aware of how many farmers and gardeners were themselves trying experiments in organic cultivation, and how much more valuable their work would be if these experimenters had any means of comparing notes and learning from each other.

The desire for some clearing-house of information was frequently voiced by my correspondents. By 1945, the demand had become so great that an attempt had to be made to translate wishes into action. A group of men and women representing farmers, gardeners, doctors, dentists, housewives and students, met in London and took the first steps to form the Soil Association. It took nearly a year to thresh out the

Constitution, but the new Society was eventually launched at an inaugural meeting in May 1946. By that time it had already grown into something much bigger than a mere information centre. Its three declared objects are:

(1) To bring together all those working for a fuller understanding of the vital relationships between soil, plant, animal and man.

(2) To initiate, co-ordinate and assist research in this field.

(3) To collect and distribute the knowledge gained so as to create a body of informed public opinion.

The Association is managed democratically by a Council (elected from among the members) which is assisted by a Scientific and Technical Panel. (Names and descriptions of the Panel and the 1948 Council are given shortly.)

By the end of 1948, over 2000 members and associates had joined the Association, representing among them over fifty different professions. While the bulk of these members are naturally citizens of the British Isles--where the Organization started--the Association is already on the high road to becoming an international body. It has members in all the English-speaking countries, in many European countries, and one or two in India and the Middle East.

Members are kept in touch with each other, and with the latest development in organic research, through a quarterly illustrated journal and a monthly news bulletin. A Research Fund has been established and is steadily growing, 25 per cent of all members' subscriptions being allocated to this.

By the autumn of 1947 the Association had so grown in numbers, in strength, and in influence, that the Haughley Research Trust decided to delegate its work to this new body.

Before leaving the work of the Trust to follow this new development however, a few of the interim observations of these early days are, I think, worth recording. In the case of wheat, for example, by the sixth generation, the proportion of small and withered grain was so great in the chemically grown wheat that, when dressing over sieves in order to recover a sample of a certain size of seed, twelve sacks had to be dressed in order to obtain eight. Only ten sacks of the compost-grown crop were needed in order to obtain the same amount.

Beans reacted adversely to the absence of animal manure quicker than any other crop. In the first generation the compost-grown beans yielded 20 bushels per acre and the ones grown with fertilizers 18 bushels per acre. In the second generation (1945) the compost beans went up to 28 bushels, but those grown chemically fell to 8½ bushels. A likely explanation is that legumes are directly dependent upon the activity of micro-organisms--the nodule-forming bacteria certainly, and probably mycorrhizal association as well. Another probable factor is the greatly increased resistance to frost that occurred in the compost-grown beans. In the hard winter of 1945 hardly a plant of this crop was lost, whereas fully 30 per cent of the chemically grown beans succumbed. The explanation for this probably lies in the increased root development which follows compost treatment. (See Plate XIV.)

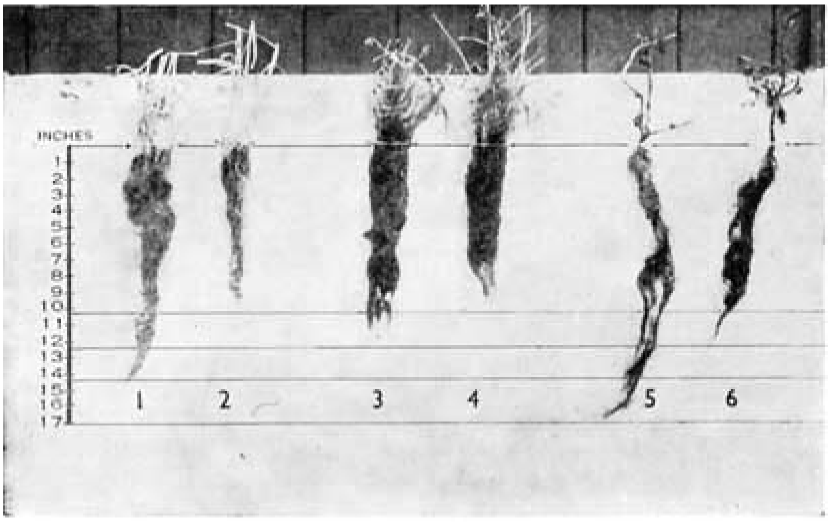


PLATE XIV

1943 Crop	No. in Plate	Length of root	Treatment at time of sowing	Previous cropping and treatment
Wheat	1	15"	Nil	1942. Beans Sheet-composted
	2	10"	5 cwt. per acre Ammoniated Bone Limphos	1942 Clover First cut taken Second cut ploughed in
Oats and Tares	3	12"	Nil	1942. Barley treated with sewage sludge
	4	10"	5 cwt. per acre Ammoniated Bone Limphos	1942. Barley treated with Limphos and Sulphate of Ammonia
Beans	5	17"	Nil	1942. Wheat 1941. Fallow 1940. Kale, grown with compost, the residue fed off with sheep
	6	12"	5 cwt. per acre Ammoniated Bone Limphos	1942. Oats 1941, half fallow. Mustard fed off with sheep.*

*This field now belongs to the 3rd (mixed) section.

Barley on the other hand has so far almost always yielded the heaviest crops on the chemical section.

I attribute this to the very short growth period of this plant. My experience, when comparing compost and chemically grown crops by eye, is that in the early stages of growth the latter usually look the more forward of the two. If at that stage you dig up some of the plants, the difference in the root development is startling. Later, the compost-grown crop, having first established a tremendous root system, starts its visible top growth and soon catches up and finally passes the other, but this process takes a certain time. It is possible that Spring barley, which is shallow rooted and very quick growing, can thus be more readily stimulated inorganically, but it is also true that chemically grown barley is much more liable to lodge at harvest time than the stiffer-strawed compost-grown crop.

When the new management took over the direction of the work in 1948 it was decided to sow all three sections once more with seed of common origin, thereafter each section will again produce its own seed for all crops for which this is feasible. This self-contained seed policy will continue for a minimum duration of the next rotation period. In consequence another seven years must elapse before grain of seventh generation stock is again available, therefore from the 1948 harvest (the last under the old management), wheat and barley from all three sections are being subjected to feeding tests by independent research workers so that there shall be some basis of comparison at the end of the next rotation period.

Early in the work at Haughley, a comparison was made between compost and farmyard manure. Potatoes on the organic section, and brussels sprouts on the mixed section being chosen for this test.

Four acres of potatoes received F.Y.M. and compost alternately in acre strips, the F.Y.M. at the rate of twelve loads per acre, the compost at the rate of six loads per acre. At the flowering stage no difference could be observed between these strips. (This has been recorded in photographs, see Plate XIII.) At harvesting the same uniformity of yield and size in the potatoes appeared to exist, but representative rows were gathered and weighed to test this. The results were as follows:

	6 loads Compost		*12 loads F.Y.M.*	
	ton	cwt.	ton	cwt.
King Edwards (per acre)	7	9½	7	19
Majestic (per acre)	12	17	13	3½

Twice the quantity of F.Y.M. thus resulted in only a few hundredweight increased yield. (See Plate XIII, Figs. 1 and 2.)

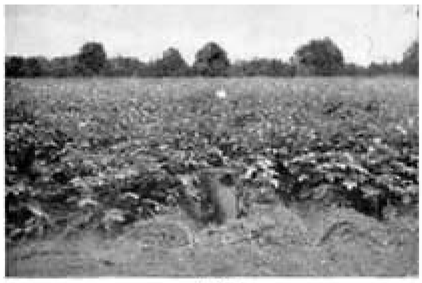


Fig. 1

Fig. 2

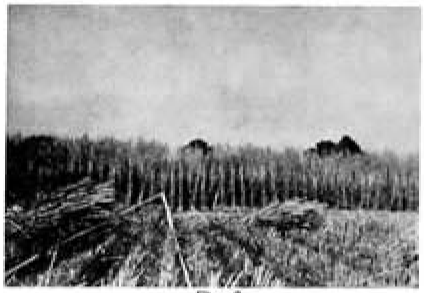


Fig. 3

Fig. 4

PLATE XIII. *Fig.* 1. Majestic potatoes. Right of flag 10 tons farmyard manure. Left of flag 5 tons compost. Photographed July, 1942. *Fig. 2* as *Fig. 1* showing potatoes in rows at harvest, October, 1942. *Fig. 3.* Taken from same place as *Figs. l & 2* showing oat crop. Harvest 1943. *Fig. 4.* More distant view of oat crop. (NOTE. *This field has received no artificial manure of any kind for over twelve years.*)

Health. The crop was not sprayed. Some disease was present in the King Edwards; more in those grown with F.Y.M. than in those grown with compost. The Majestics were all equally free from blight, but some of those grown with F.Y.M. showed slight traces of scab, especially in those strips grown with long muck, and where the field is a little wet. The compost-grown ones all had beautiful smooth fine skins. After six months storage in clamp the keeping quality and size were also determined, with the following results:

KING EDWARDS

Size*	Grown with Compost Total per cent	Sound per cent	Diseased per cent	Grown with F.Y.M. Total per cent	Sound per cent	Diseased per cent
Ware	80.74	74.30	6.44	73.98	67.63	6.35
Seed	15.35	14.30	1.05	20.82	19.65	1.17
Chatt	3.91	3.91	—	5.20	5.20	-
Total	100.00	92.51	7.49	100.00	92.48	7.52

MAJESTIC

Size*	Grown with Compost Total per cent	Sound per cent	Diseased per cent	Grown with F.Y.M. Total per cent	Sound per cent	Diseased per cent
Ware	86.98	84.60	2.38	82.44	80.67	1.77
Seed	9.91	9.52	.39	14.02	13.65	.37
Chatt	3.11	3.11	-	3.54	3.54	-
Total	100.00	97.23	2.77	100.00	97.86	2.14

*Ware = Too big to pass through a 2-inch mesh.
Seed = Passing through 2 inches but not 1¼ inches.
Chatt = Passing through a 1¼-inch mesh.

It will be noted that the difference in keeping quality between the potatoes grown with compost (at six loads per acre) and those grown with F.Y.M. (at twelve loads per acre) is negligible, being slightly in favour of the compost in the case of the King Edwards, and vice versa in the case of the Majestic. It is interesting however that the compost produced a markedly higher percentage of large potatoes in both cases. This crop was followed by oats. (See Plate XIII, Fig. 4.) It was not possible to harvest these strips separately but the photograph clearly shows the greater length of straw in the compost strip (the division is marked by the arrow). The total crop yielded 80 bushels per acre. This particular field, incidentally, has received nothing since 1930 but farmyard manure or compost, at an average rate not exceeding 5 tons per acre per year.

Six acres of brussels sprouts received basic slag throughout, and F.Y.M. and composts of different types in acre strips. This time all at the rate of 7 tons to the acre.

Key to types used:

F.Y.M. (*a*) Farmyard manure from a hill, with a little chalk added when building.

F.Y.M. (*b*) Farmyard manure unrotted direct from yards.

S.M.Compost made from straw, F.Y.M. and sewage sludge.

M.B.Compost made from straw, F.Y.M. and raw blood.

S.B.Compost made from straw, sewage sludge and blood.

C.I.Standard compost, Straw, and F.Y.M. (mainly pig).

All the composts, of course, were made with the necessary admixture of chalk and soil. One acre was left untreated as a control.

Result. Plants of both F.Y.M. strips were bigger than those in the control acre. At first those with F.Y.M.(*b*) were better than F.Y.M.(*a*). Later this was reversed, suggesting that the undecomposed cellulose in F.Y.M.(*b*) developed a depressing effect on growth.

All compost strips produced better plants than the F.Y.M. as to size, and were markedly freer from caterpillar attack. The difference between the three composts S.M., M.B. and S.B. was negligible, if anything those which included blood were slightly better than S.M.

The results of C.I. are interesting. Two acres were treated with this. One acre received a very well-made batch of the compost, weather conditions being just right, and correct temperatures being obtained in the course of manufacture. The other acre received compost made in exactly the same way, but under less favourable conditions, so that the resulting product was rather too wet.

The plants on the first of these acres were outstandingly the best in the field, both as to size and colour and as to freedom from insect attack. The second acre, although better than those receiving F.Y.M., were less good than those receiving M.B. and S.B.

This demonstrated the importance of correct making, and the fact that chemical composition plays only a secondary part in the value of compost.

These results were noted by independent observers.

By the summer of 1948 the transfer of the Haughley Research Farms to the Soil Association was completed, and the following year a booklet was issued describing the research programme and appealing for funds to carry it out. As this booklet brings the whole story of the enterprise up to date I now reproduce below the major portion of it. The document itself, with a complete field history and guide, is obtainable on application to the Soil Association, price 2s.

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MR. R. ST. BARBE BAKER. Founder of Men of the Trees.

DR. K. E. BARLOW. Medical Practitioner.

MISS MAYS E. BRUCE. Author and originator of Q.R. Herbal Activator for Compost.

MISS M. DE BUNSEN. Journalist.

MR. HENRY DECK. Director of Ransome Sims & Jefferies.

MR. R. DE LA MARE. Publisher.

MR. L. F. EASTERBROOK, O.B.E. Agricultural Correspondent.

MR. ROLF GARDINER.Farmer and Landowner.

MR. H. J. MASSINGHAM. Author.

SIR CECIL OAKES. C.B.E. Solicitor.

DR. INNES PEARSE. Medical Practitioner and Director of Pioneer Health Centre, Peckham

LT.-COL. W. E. SHERWELL COOPER. Horticultural Adviser.

MR. E. MAURICE WOOD. Farmer and Miller.

MR. C. D. WILSON. (*Hon. Sec.*). Manager of Pioneer Health Centre.

THE SOIL ASSOCIATION
PANEL OF EXPERTS

Chairman:
DR. G. SCOTT WILLIAMSON, M.C.

LORD TEVIOT (*ex officio*).

DR. G. E. BREEN. Medical Practitioner and Editor of Medical Press.

MR. E. BRODIE CARPENTER. Dental Surgeon.

MR. C. C. J. BULLOUGH. Farmer and Sanitary Engineer.

MR. N. P. BURMAN. Bacteriologist.

MR. J. L. H. CHASE. Horticulturist.

MR. D. J. DUFFY. Farmer (Bio-Dynamic).

DR. IDA LEVISOHN. Botanist and Mycologist.

MR. A. A. McINNES. Retired Banker.

SOIL FERTILITY--THE BASIS OF HUMAN SOCIETY
GUIDE TO A VITAL RESEARCH

THE HAUGHLEY RESEARCH FARM EXPERIMENT

Published by the Soil Association in the interests of the human race.

For too long the emphasis in food production and the focus of agricultural research and advisory services has been on increased yields, to the exclusion of quality. This policy has led to soil exhaustion and has been accompanied by an increasing incidence of disease in plant, animal and man.

It is urgent and vital that we should now turn our attention to the study of quality and the means of restoring and maintaining it. If food is deficient in vitality and in the minerals and vitamins essential to health, mere bulk will not sustain vigorous life.

When quality is sacrificed to quantity, total food supply diminishes. This sounds like a paradox, but the truth of it is proved by the ever-increasing area of man-made deserts.

Where quality is put first, soil fertility and crop yields are maintained indefinitely. Where quantity is the aim and quality is neglected, soil devitalization and exhaustion lead ultimately to dust-bowl, desert and famine.

This booklet describes the concerted effort of a disinterested and public-spirited body of men and women determined to prove the importance of quality in living things, and to seek its source in the soil from which they gain their nourishment. It therefore directly concerns everybody.

PART I
PRELIMINARY STATEMENT

The Research here outlined represents a fundamentally new approach to the study of the Soil, in that it relates Fertility to the qualitative aspects of Nutrition.

It is based on systematic and carefully-controlled differential comparisons, conducted on a farming scale, and will extend over many generations of crops and livestock. The main purpose is to ascertain the effect of biological soil activity--directly upon plants and indirectly upon animals fed thereon

(i) as reflected in quantity and quality of output;

(ii) as affecting genetic and transmissible characteristics;

(iii) as influencing positive health and disease-resistance.

The results obtained will clearly have an important bearing on questions of human nutrition and will be placed at the disposal of all workers in that field.

The foundation for this work has already been laid.

THE FIRST £10,000 IS NOW URGENTLY REQUIRED
TO CARRY IT FORWARD THROUGH ITS NEXT STAGE

This research is being conducted by the Soil Association under the jurisdiction of a *Board of Referees* consisting of the following:

The Rt. Hon. Sir John Anderson, G.C.B., G.C.S.I., G.C.I.E., M.A., D.SC., LL.D., F.R.S., M.P.

The Lord Forrester of Corstorphine, M.A., F.I.I.A.

The Rt. Hon. Lord Hankey, G.C.B., G.C.M.G., G.C.V.O., LL.D., D.C.L., F.R.S.

F. C. Scott, Esq.

The Rt. Hon. Lord Justice Scott.

Sir George Stapledon, C.B.E., F.R.S., M.A.

THE CASE OUTLINED

Statement by Referees

"Humanity has been badly frightened by the invention of the atomic bomb. Yet the slower but more widespread devastation wrought by exhausting the soil upon which we depend for subsistence, is ignored by the majority of people, who think of calamity only in terms of sudden disaster or of war.

"Wasteful exploitation of the soil's fertility is due in part to the desire for quick cash returns, but in a greater degree to ignorance. Many scientists and agriculturalists now realize that their knowledge of the natural processes underlying soil fertility is incomplete. They recognize that these processes are only partly explicable in terms of agricultural chemistry, and that the purely inorganic approach to the study of soil science is a line of thought as dead as the mechanical determinism of nineteenth-century physics.

"'Dead' is the appropriate word, for the missing factor is that of life itself. Biology is the science of life, and Ecology is that part of it which treats of the relationship between living organisms and their environment. We have reason to believe that soil biology and soil ecology--both comparatively neglected branches of science--can fill the gaps in our knowledge of the foundations of health in the soil and in the plants, animals and human beings which depend upon it, directly or indirectly, for sustenance. This broad conclusion is based upon a considerable amount of evidence, much of which has been published.

"The Soil Association, a non-profit-making organization, supported by many prominent members of the agricultural and medical professions, was formed to link together people in many lands who are thinking and working upon these lines. It is concerned especially to meet the growing demand for research into the wider implications of soil vitality and the right ways of maintaining and promoting it.

"It is not a fantastic statement to say that in twenty years' time people may be dependent for their lives upon the results of research in this fuller biological sense. For man-made deserts, mass migrations and widespread malnutrition and disease, all proclaim the failure of research and education, upon existing lines, to prevent the waste and destruction of soil fertility.

"Circumstantial evidence has been accumulating in recent years to the effect that maintenance of a correct biological balance in the soil is of critical importance to the vitality of plants, animals and man. We consider this evidence significant enough to warrant the view that further investigations are a matter of national urgency.

"Many people will ask why this work could not have been done at established research stations. The answer is that the ecological aspect of the problem demands experimental work upon the full scale of ordinary farming operations, for which the small-plot system usual at agricultural research stations is inadequate.

"The distinguishing, and in some respects novel, feature of the Haughley method of research will be the comparison of contrasted systems of soil management.

1. OVER A PERIOD OF YEARS, SO THAT CONTINUITY IS SECURED.
2. OVER SUCCESSIVE GENERATIONS OF PLANTS AND ANIMALS NURTURED IN THE SAME WAY, SO THAT CUMULATIVE EFFECTS MAY HAVE FULL PLAY.
3. ON A REGULAR ROTATIONAL BASIS AND ON A FIELD SCALE; SO THAT ALL OTHER CONDITIONS MAY BE THOSE OF ORDINARY FARMING PRACTICE, and
4. ON AREAS OF LAND AS NEARLY AS POSSIBLE COMPARABLE AS REGARDS SOIL TYPE, DRAINAGE AND OTHER BASIC FACTORS.

"The 210 acre experimental farm where this work is now in progress has been divided into three sections. In No. 1 section no mineral fertilizers are used, but only animal manure and vegetable residues in the form of organically-prepared compost. In No. 2 no animal manure is used, but inorganic chemical fertilizers are supplemented by ploughing in green crops. No. 3 is run on the lines of orthodox mixed farming; that is to say, farmyard manure and compost are used in conjunction with both organic and inorganic fertilizers. This third section thus provides the control for measuring the different results and comparative values of the systems used on sections 1 and 2.

"If soil fertility and cropping experiments are to be carried to their logical conclusions, feeding experiments on farm animals as well as laboratory animals will be needed. *These will have to be continued through many generations of crops and livestock.* So far as can be discovered, there is no provision at existing research stations for this integration of manuring and feeding through successive generations. Yet without it, no experiment seeking to determine ultimate food values can be complete."

Signed by:
JOHN ANDERSON
HANKEY
F. C. SCOTT
LESLIE SCOTT
R. GEORGE STAPLEDON
FORRESTER

PART II
PAST HISTORY AND FUTURE PROGRAMME

Research on the lines proposed in Part I cannot be done quickly. To determine causes, effects must be studied over a long period of time. More and more people are beginning to realize that *health does not lie solely in a planned diet, but also in the way in which that diet is grown.* Even in mineral content there is a pronounced difference in the same vegetable when grown on fertile or infertile soil. In vitality--a much less measurable quality--the difference may be incalculably greater. How much greater we do not as yet know.

Biology and ecology, working hand in hand with chemistry and physics, may supply the answers to these questions. Meanwhile it is possible to observe certain effects on the health and stamina of plants, animals and human beings, following upon organic soil treatment. Such effects are often immediate and dramatic, But they will not convince the independent observer until the hidden processes out of which they arise can be more fully explained. To diagnose the weakness in presentday soil science, orthodox methods of cultivation and soil treatment must be practised under controlled conditions, alongside those methods of organic cultivation which experience suggests (though science has yet to prove) may supply the missing factor. The groundwork of such field experiments has already been laid at Haughley by the Haughley Research Trust.

The Haughley Research Trust

This Trust was founded in 1938 by the late Miss Alice Debenham to investigate the causes of positive health in crops and livestock, and particularly the relationship between the health of the soil and that of the crops and animals raised upon it. In 1940, 210 acres of land, partly owned by the Trust and partly leased, was divided into three sections as described in Part I.

The arrangement of these sections has been carefully made so that any slight differences in soil type are equally represented in all three. When the Soil Association took over the Haughley Research Farms from the Haughley Research Trust, it was decided:

1. That the experiment should be designed to compare the three methods of farming and to answer the following questions. Does organic farming:

(*a*) Produce food of better quality than the other two methods;

(*b*) Increase the resistance of plants and animals to disease; and

(*c*) Enhance the fertility of seed and animal.

2. That the division of the fields, as made by the Haughley Research Trust in 1940, should remain, and should comprise an all-organic and an orthodox section, each supporting identical classes of livestock of common origin, and a stockless section.

> The livestock on the all-organic and the orthodox sections will comprise in each case a small herd of Guernsey cows, a flock of poultry and two breeding sows with their progeny. The foundation stock for these flocks and herds have now been purchased. In the case of the cattle heifers have been obtained in pairs from self-contained herds where the past history is known, each pair being by the same bull and out of cows of similar records, this being the most likely way to obtain pairs of animals with fairly uniform characteristics so that one of each pair can be placed in each herd.
>
> In the case of the poultry the auto-sexed breed Golden Cambar has been chosen, and the setting eggs for the foundation stock all originate from the same breeding pen of birds.
>
> The foundation sows for the two herds of pigs have been picked from litter sisters in the existing herd of Essex pigs which have been home-bred at Haughley for several generations.
>
> Much consideration was given by the Soil Association experts to the difficult problem of the sires. Finally it was decided that as the sire is the most important factor in breeding, one bull would have to be used for both herds of cattle and one boar for both herds of pigs. This has obvious disadvantages, but it is considered that the advantages outweigh the disadvantages. These sires will be kept and treated as part of the organic herds, but will be used on both. To those who have an organic bias this will seem to give an advantage to the mixed herd, but it is much better to do that than to give the advantage the other way round.
>
> During the first rotation, or stabilizing, period no arrangements can be made to feed the produce of the stockless section to livestock at Haughley, but produce from all three sections will be offered to nutritional research laboratories for feeding tests.

3. That the attempt to have identical rotations and to make a year by year, field by field, comparison is the wrong policy for the following reasons:

(*a*) Basically the experiment was designed to compare three methods of farming. Each section, therefore, should represent, as far as possible, the very best farm of its type. Clearly a rotation which was right for one method of farming would not necessarily be right for another.

(*b*) In practice, it would not be possible to carry out all field operations simultaneously in all three sections, so that an accurate field by field comparison would in any case seldom be possible.

4. That in view of the above, the comparison must be a long term comparison, not less than rotation period by rotation period.

5. That since the aim must be to make each section the best possible farm of its kind, the general management, cropping, rotation, manuring, etc., must in each case be put under the direction of a recognized expert in that method of farming.

> The supreme advantage of this system of triple control is that with three experts, each satisfied that his own method is the best, and each competing with the other to demonstrate this, we shall achieve a degree of impartiality such as would be impossible under any single directive.

The following have accordingly been appointed Directors of Farming Operations in the three sections:

Organic Section: Mr. Friend Sykes and Mr. D. J. Duffy.

Stockless Section: Mr. F. P. Chamberlain.

Orthodox Section: Mr. William Alexander.

6. That while the first object of the experiment is to compare three methods of farming, the second is to arrive, if possible, at a scientific interpretation of any differences that may result. For this purpose a full-time experimental officer has been appointed.

> In the early years at Haughley a beginning was made to determine and compare the biological activity of the soil in the different sections by use of the cellulose decomposition test. (See Technical Ref. No. 9.) Earthworm experiments were also started. These experiments will be continued under the supervision of the experimental officer, and frequent soil tests will be made in all three sections. These will include the usual chemical analyses for phosphorus, nitrogen, potash and lime, and also biological tests to determine the extent of fungal activity and, so far as possible, the behaviour of the soil population generally, including earthworms. Particular attention will be paid to mycorrhizal activity, and the relationship of this to the different soil treatments. All field tests will be supplemented wherever possible by pot experiments under laboratory conditions. These various tests will continue throughout the whole course of the experiment so that the results of them can later be correlated with any results obtained in feeding experiments. A great deal of importance is attached to the mycorrhizal examinations. Dr. Rayner has stated: 'It is my deliberate opinion, as has already been stated elsewhere, that variations in

mycorrhizal response can be used as an index of health and growth, and that correct interpretation of these responses is an essential move towards better control of the soil conditions promoting health, vigour and maximum resistance to disease. Research along the lines indicated is yielding results of practical value to forestry.

'As a first step it is essential in the case of every species known to be a regular mycorrhiza-former to learn to recognize the mycorrhizal characters associated with health and optimal growth of the host. In wild species this is not difficult, but in those long in cultivation the best that can be done is to obtain a composite picture by numerous comparative observations on individuals from various sources and of varying vigour. The next step involves comparative study throughout the growing season in the species under observation of experimental material subjected to various soil treatments in the field and, if possible, also under controlled conditions.'

This view seems so obviously sound that eventually a permanent resident member of the experimental staff will probably have to be a botanist or mycologist specially trained in this work.

Note from Soil and Health Library: The edition used to render this book for the internet contained an errata notice inserted at this point in the book, stating:

Correction for page 186
CORRECTION

Mr. Alexander is no longer directing the orthodox (mixed) section of the Research Farm. The Council of the Soil Association is in contact with a probable successor, but at the time of going to press it is regretted that a final announcement as to the name cannot yet be made.

7. *Costing.* The prime purpose of the experiment is, of course, to determine which of these three methods of farming is the most successful in obtaining vitality in all its products, on what foresters call a sustained yield basis. Taking a long term view, the method which proves the best in this respect must, of course, be ultimately the most profitable. Nevertheless, it was agreed that it was important to compare the economic aspect on a shorter term basis as well. Each section will, therefore, be costed separately and the results between them compared, but this comparison will also be on a rotational basis and not year by year.

The Ministry of Agriculture has agreed to give the Management Committee a free hand in planning these experiments, so as to free the farm from cropping orders and similar restrictive regulations which have hitherto hampered the experimental side of the work. The Soil Association is also indebted to the National Research Station at Rothamsted for valuable co-operation and advice.

An issue of 3 per cent Debentures has been made, and fully subscribed, to cover the purchase of the land and buildings and to provide sufficient working capital to initiate the next stage of the experiments. To staff, equip and carry it through, further financial support is needed immediately.

Haughley and the Soil Association

The Soil Association was established several years after the initiation of these experiments at Haughley, but its Executive Council is so firmly convinced of their potential importance that it has decided not only to sponsor this appeal but to accept the task of controlling and directing the future developments of the work.

In this decision it was influenced by the suitability of the land, the availability of accommodation for research staff, and in particular by the value of the seven years' preparatory groundwork which had already been done. *These conditions could not be found elsewhere in this country.*

To carry the Haughley project through its next stage of development, commencing in January 1949, which includes feeding and breeding experiments within two of the three self-contained sections, the Soil Association is launching an appeal for a special research fund of at least £10,000. The group of prominent people who have signed the first part of this document are serving as a Board of Referees. The duties of this Board are:

1. To ratify the appointments of the scientific and technical advisers and consultants.
2. To select official observers to watch and report upon the conduct and progress of the experiments.

Four out of six of these Referees are outside the membership of the Soil Association and have had no previous connection with the work at Haughley. *In this fact lies the public's guarantee of complete impartiality and objectivity in the recording and interpretation of results.*

The Soil Association is convinced that the interlinked subjects of soil conservation, soil fertility and nutrition are as vital to the future of the world as is the control of atomic energy. It invites your serious consideration of the problem of feeding the increasing populations of the world for the next hundred years on an inadequate and diminishing acreage of partly exhausted soil. It believes that Haughley, with its background of seven years of preparatory work, offers the optimum conditions for research into this problem.

The sum of money for which this appeal is made represents only one five-hundredth part of 1 per cent of the sum which is said to have been expended on atomic research. We ask you to back this project financially, to the utmost of your ability, in sober realization that the land is a trust in which is vested the health and well-being of our children and their children after them.

This is a vital issue which we all must face.

Do we want to go down to history as the generation which was too preoccupied with instruments of death to study the resources of life? Or shall we be remembered as those who first stemmed the advance of sterility by restoring and maintaining the vitality of the soil on which all life depends?

THE HAUGHLEY RESEARCH FARMS
DIRECTORS OF FARMING OPERATIONS

Organic Section: Mr. Friend Sykes and Mr. D. J. Duffy.

Mr. Sykes is a well-known organic farmer. His 700-acre farm on the Wiltshire Downs is entirely self-contained, providing all the feeding stuffs necessary for a large herd of Guernsey cows and also growing very heavy crops of corn, no fertilizers being used. Mr. Sykes is also well-known as the author of *Humus and the Farmer.*

Mr. Deryck Duffy is the Director of Westhall Farm Schools, Oyne, Aberdeenshire, which is a well-known training centre for students of both sexes in practical agriculture and horticulture. Some of the farms are run on organic lines and some on orthodox lines.

Stockless Section: Mr. F. P. Chamberlain.

Mr. Chamberlain is a very well-known Oxfordshire farmer. He farms an extensive acreage and is a foremost exponent of green manuring. Much of his land has been successfully farmed without any livestock since 1894.

Orthodox Section: Mr. William Alexander.

Mr. Alexander farms 1,200 acres in Kent. He was for many years a member of Kent War Agricultural Committee and is recognized by all authorities as one of the very best mixed farmers in the country. He has a famous self-contained herd of Friesian cattle.

EXPERIMENTAL OFFICER
Mr. N. L. Ferguson, B.Sc.

Mr. Ferguson obtained his degree in 1935, and a post-graduate travelling scholarship to the States and Canada. Since then he has had considerable research experience and was for three years botanist at St. Ives Research Station and from 1943 to 1947 was Research Assistant to the North of England Animal Diseases Research Committee at King's College, Newcastle. During the war he was in the Sudan Government Agricultural Service.

FARM MANAGER
Mr. E. K. Allan

Mr. Allan is a thoroughly practical farmer, having farmed all his life both here and in Australia. He left the National Agricultural Advisory Service to take up his post at Haughley.

SCIENTIFIC AND TECHNICAL ADVISERS to the project include Biologists, Botanists and Mycologists, Agricultural Chemists, Pathologists and a Veterinary Surgeon.

The Soil Association maintains a guest house at Haughley and welcomes visitors to the research farm. All communications including inquiries for accommodation, application for membership, and donations to the research work, should be addressed to

The Organizing Secretary, The Soil Association Ltd.,
New Bells Farm, Haughley, Suffolk.

CHAPTER IX
FACING THE IMPLICATIONS

'Promotion of health is a more desirable objective
than is the treatment of sickness.'
Dr. J. P. S. Jamieson

It is my opinion that no plan for a new Britain can be laid on a sound foundation unless the question is first answered as to whether a connection exists between biological soil activity and health. In this chapter I wish to amplify that statement. In order to do so, I must ask you to imagine that the experiment outlined in the last chapter has been carried out, and that the result of it has been to prove that wherever the ecological balance of the soil is seriously disturbed, disorders in crops, animals, and man follow.

That such a result is at least possible must, I think, be conceded as a result of the evidence that has been presented. If it should indeed prove to be the truth, then the implications would reach into almost every activity within the life of the nation.

A short time ago Sir William Beveridge, broadcasting on his report for social security, said that security against sickness was one of the two factors of reconstruction that did not raise any big political issue, but this would not be true if it were shown that the primary factor in the prevention of sickness lay in soil management, for in that event, any, government, if it is to fulfil its duties of serving the common good, would have to exercise a wide control, not only of land utilization and management, but also over the whole range of subsidiary interests that at present handle the production and distribution of the nation's food supplies, as well as over the methods employed for disposing of municipal wastes. Among those concerned in this wide range of activities are some very powerful vested interests, and thus any programme for the promotion of health that was based on soil fertility would raise political issues of the first order.

I now ask you to face some of these issues squarely and see where they lead us, because as citizens of a democracy, the matter will rest ultimately in your own hands.

First and foremost would be the need for a complete revolution in outlook. If the nation's health depends on the way its food is grown, then agriculture must be looked upon as one of the health services, in fact the primary health service. 'It is important . . . to outgrow the attitude of confining the term health services to what are really sickness services. The nation needs sickness services, but a nation which regards them as a substitute for health services . . . is going to find the confusion expensive in money and in suffering. Such confusion is the easier to fall into because many of the developments most vital to health are considered primarily from other standpoints, and many of the persons who can do most to assist health are not usually regarded, and do not regard themselves, as having special responsibilities in that direction.' (P.E.P. Report on British Health Services, 1936).

Once agriculture came to be regarded as a health service the only consideration in any matter concerning the production of food would be: 'Is it necessary for the health of the people?'; that of ordinary economics would take a quite secondary place.

In deciding whether or not new medical clinics should be opened or new schools built, we do not ask 'Will they pay?' but 'Are they needed?' We regard them as necessary social services and as such the whole community is expected, and in the main is willing, to pay for them. The greatest social service of all is, or should be, the provision of the people's food.

If fresh food is necessary to health in man and beast, then that food must be provided not only from our own soil but as near as possible to the sources of consumption. (See *Case for a Service Agriculture,* Technical Ref. No. 10.) If this involves fewer imports and consequent repercussions on exports, then it is industry that must be readjusted to the needs of food.

If such readjustment involves decentralization of industry and the reopening of local mills and slaughter-houses, then the health of the nation is more important than any large combine. That the welfare of the people as a whole must in future take precedence over all narrow interests is a principle which has been accepted. This acceptance has been expressed by Lord Elton in the following words: 'What are the true objects of industry and commerce? Presumably they are the same as all activities within the state, the material and physical well-being of all its citizens.' (*St. George or the Dragon.* Collins, 1940).

If health demands adequate supplies of humus for the soil, then means must be found to provide it; if this involves, among other measures, the complete reorganization of existing sewage and town waste disposal plants, then local authorities must put the needs of the soil first. Actually the claims of the ratepayers coincide in this case with those of the soil, for this is a reform which would result in practically every case, in a reduction in rates, (See Technical Reference No. 11.) but even if it had the reverse effect, it would be better to receive health in return for rates, than to spend the money in a perpetuation of the present wasteful system.

If a big increase in livestock is another necessary measure for the preservation of soil fertility, then these must be kept, imports of meat being controlled to whatever extent is necessary. If this upsets the world of finance, and reduces dividends to investors whose capital is abroad, then still the nation's health is more important than dividends.

If further investigation should prove that certain chemicals injure the health-giving powers of the soil, then application of these chemicals must be forbidden. If this cuts across vested interests, then the nation's health is more important than any vested interest, and are we not fighting this war to end exploitation of all kinds? If, in order to serve the needs of the soil, and thereby serve every citizen of the land, instead of just a few, it becomes necessary to turn the whole organization of food production, preparation, and distribution, over to public ownership; if farmer, miller, butcher, baker--all of us concerned with food--have to be incorporated into one vast social service, decentralized, but nevertheless unified, equivalent to the proposed State Medical Service, then even so drastic a step as that must be taken, for *still* the nation's health comes first. These possibilities are an indication of what I mean by a revolution in outlook. Such a revolution may be the price of health, are we prepared to pay it?

If the purpose of the planners of the New Britain is genuinely to prevent in future the exploitation of the many by the few, then of all exploitations the most anti-social is surely exploitation of the national health. Thus the more the implications are considered, the more urgent does it become to provide a definite answer as to whether health is dependent on the activities of the soil population.

Having plunged straight into some of the problems and complexities which an affirmative answer to this question would provide, I shall now attempt a more practical approach to the problems involved. In doing so, I am assuming to a certain extent the changed outlook with regard to the position of agriculture, for given our initial assumption, that soil fertility has been *proved* to be the basis of health, and recognized as such, it is hardly conceivable that such a change would fail to follow.

But a changed attitude has got to be translated into action. We need to readjust the balance of our whole national life as between farm and industry, as between man and the machine, and as between real wealth and money. Machines and money must be restored to their rightful place as the servants of man. There is a grave danger at present that we may allow them to become our masters.

What practical steps could be taken then, by a government likely to be chosen by such a democracy as ours, to bring about these necessary reforms? It is a formidable task, but luckily the immediate post-war Government will have a unique opportunity, such as is never likely to recur, for initiating a really constructive land policy. This is because, firstly, it will be a long time before we shall be in any danger of having to restrict food imports. The surplus farm produce of all countries will, for many months and possibly years, be needed to replenish the European larder. We shall, therefore, for some time to come, be forced to rely to a very large extent on our own soil, as at present. Secondly, it is probable that in any case we shall never again see a complete return to conditions in which home manufactured goods can be sure of a foreign market in return for agricultural produce, for apart from the fact that many of the countries where we used to sell now produce their own goods, the peoples of the new worlds, the United States of America, the Dominions, and also some of the Colonies, are becoming alive to the danger that threatens them from soil erosion, and the even greater incidence of loss of soil fertility; a danger amounting to nothing less than extinction.

'For as a result solely of human mismanagement, the soils upon which men have attempted to found new civilizations are disappearing, washed away by water and blown away by wind. To-day, destruction of the earth's thin living cover is proceeding at a rate and on a scale unparalleled in history, and when that thin cover-the soil-is gone, the fertile regions where it formerly lay will be uninhabitable deserts; already, indeed, probably nearly a million square miles of new desert have been formed, a far larger area is approaching desert conditions, and throughout the New World erosion is taking its relentless toll of soil fertility with incredible and ever-increasing speed.' (Jacks and Whyte, *The Rape of the Earth.*)

It is difficult to take in the speed of this devastation. Jacks and Whyte bring home its true significance by telling of a traveller to South Africa only seventy years ago who stated that 'the greatest obstacles to pastoral farming in the Orange Free State were the natural richness and excessive wetness of the pastures. The rich grasses have now gone and the dried-up pools and springs are remembered only in place-names like Bloemfontein.. . .

'A nation cannot survive in a desert, nor enjoy more than a hollow and short-lived prosperity if it exists by consuming its soil. This is what all the new lands of promise have been doing for the last hundred years, though few as yet realize the full consequences of their past actions or that soil erosion is altering the course of world history more radically than any war or revolution.'

It seems only too clear that these countries face a race against time if they are to escape the fate of the ancient civilizations of north China, Persia, Mesopotamia, and north Africa, all of which now lie buried under man-made deserts.

It is important to remember how the new deserts started, because it concerns us very closely. The new worlds were offshoots of the old. They were 'colonized', they 'could not', to quote Jacks and Whyte once more, 'have been developed without the help of foreign capital in the form of money, goods and services, most of which was paid for by exporting soil capital--an apparently harmless procedure at a time when fertility was reckoned in terms of the inexhaustible supplies of plant-food minerals in virgin soils. Physical fertility was but little understood, still less was it realized that physical and biological characteristics were much more important forms of soil capital, more easily wasted and more difficult to restore, than chemical characteristics.

'To see the economic problem of erosion in proper perspective, it is necessary to recognize the part played by huge transfers of financial capital from one country to another and their repayment by drawing on soil capital. Movements of capital have been an outstanding feature of the modern world. They may truly be said to have been one of the mainsprings of progress, but capitalism has never seriously concerned itself with its repercussions on the humus content and structure of soils. Nevertheless, the repercussions have been shattering in their effect and can no longer be ignored. . . .'

These new worlds, then, must in the interests of self-preservation henceforth concern themselves with soil conservation and the restoration where possible of lost fertility. This will involve a refusal to pay for any more imports out of soil capital. Thus we shall probably be forced, in any case, to readjust the balance between agriculture and industry, since we shall no longer be able to look to these distant lands for supplies of 'cheap food' in return for manufactured goods. For this we should be profoundly thankful since it may well be the indirect means of restoring our own soil fertility.

A third factor which should assist towards this end, will be the need after the war, of finding new outlets to absorb the labour which will be released from purely war production. (This situation has not yet arisen [1947] but sooner or later it will.) There is no reason why much of this labour should not be used to increase the most fundamental of all our national assets-the fertility of our soil. The land itself could usefully absorb an impressive amount of additional labour if the needs of the soil rather than its exploitation were the primary consideration. For example, if all farmyard manure and other farm wastes were manufactured into humus outside the field, this alone would absorb over 300,000 additional workers. (Two men working together can make 1,000 tons compost per year. Average of five tons per acre per year will maintain fertility, thus two men will make enough compost for 200 acres. Average one man per 100 acres. Area of agricultural land, 32 million acres.) A further need is the large amount of land reclamation and drainage still to be done, despite the energies of War Agricultural Committees. In many cases, too, a partial return to horse traction would be, not only labour absorbing, but of undoubted benefit to the land, if only because of the additional manure thereby produced.

Captain Wilson (See Chapter VI.) has on more than one occasion noted and recorded the improved crops that result from horse ploughing on certain types of soil. This has been particularly noticeable where tractors and horse teams were at work at the same time and in the same field, the strips ploughed with horses were clearly reflected in the subsequent crops.

There is some evidence also, that heavy land soil, continuously cultivated with tractors, is becoming shallower, the opposite of the effect one would expect. (Given in evidence before the Lord Justice Scott Commission, 1942). There are two reasons for this I think; one is that on such land the pressure of the tractor (whatever the theorists may say) counteracts the lifting power of the implements it hauls, (Improved types of tractor will probably obviate this objection in time.) the other is that the depth of the tractor plough cannot easily be continually adjusted to hard, and tough, or sticky patches in a field, the presence of which is immediately felt by the horse ploughman.

Captain Wilson has given it as his considered opinion, based on personal experience, that when properly farmed, a return to horse cultivation can be justified economically on all but the lightest land. This reform alone would absorb a considerable amount of additional labour.

The provision of outside sources of humus, which would be particularly necessary to restore fertility at the outset of a changed agricultural policy, would, for a time, absorb another great labour force. Much of this work would simply entail quarrying and screening, for many of the controlled town 'tips' of ancient days now consist of humus in a condition only requiring aeration to render it fit for direct application to the land.

Howard has called these old tips 'humus mines', and their probable yield has been estimated at some ten million tons or so of finished humus. That their potential value has already begun to dawn on the powers that be is shown by an article which appeared in the *Evening Standard* of 14th November 1942:

'A vast new scheme for doubling or trebling the fertility of the land throughout the country is to be published soon by the Agricultural Research Council.

'The plan is the result of recent intensive research work designed to discover new sources of raw materials out of which fertilizers can be made. A result of it may be the gradual disappearance of the enormous refuse dumps which for years have been eyesores along the Thames estuary.

'All this material can be crushed up in machines containing revolving sledge hammers.

'The product is a compound of great value on heavy lands needing humus. . . .'

Another direct measure which could, and should, be taken in the interests of soil fertility and common sense, is to put a stop to the huge wastage of valuable soil nutrients that goes on in most of our towns and villages. Modern standards of comfort will not permit of the abolition of water-borne sewage in our cities, but a very great deal could be done towards reducing the waste involved. The excessive dilution of sewage could be avoided by arranging that rain and bath water are carried away by a separate system of sewers. This would not create any difficult engineering problem, and would have the great advantage of excluding from the sewage many poisonous industrial effluents. The sewage proper should then be properly composted with the town refuse. This latter consists of wastes of mixed vegetable and animal origin and after the removal of foreign bodies, such as broken glass and tins, it makes, when composted with sewage, an excellent manure. There already exist several examples where this system has been adopted by local authorities with very great success, and at a considerable saving in the costs of disposal. (See Technical Ref. No. 11.) It may be asked why this reform has been so long neglected. The reason is, I think, partly the reluctance of local authorities to scrap existing machinery, and partly the current error of estimating the value of a compost from its chemical composition alone. This error has a wide hold on the agricultural community and has caused in the past a smaller demand for this urgently needed reform than would otherwise have been the case. Actual experience, however, has proved to cultivators how valuable this compost can be, (See Technical Ref. No. 11.) and those authorities which are making it have found no difficulty whatever in disposing of it, in fact the demand has exceeded the supply. The demand will grow more and more as it comes to be realized how much more important, as Jacks points out, are the physical and biological aspects of soil fertility than the chemical.

At first sight, the logical use of such urban sewage compost would be for the fertilization of the area immediately surrounding the town or city concerned, but it is doubtful if such use would be biologically sound because of the concentration of so large a proportion of human waste on so small an area of land. Theoretically the waste of an entire community--plant, animal and human--should be returned to an area of land capable of supporting that community. (See Technical Ref. No. 13.)

Even at the tremendous productive capacity quoted for parts of China--nearly three people per acre, apart from livestock--this would involve distributing the annual production of compost from a town of only 50,000 inhabitants over nearly 17,000 acres. The transport difficulties of such a distribution may seem on first inspection to be insurmountable. But are they? Our coal supplies travel quite as far and the trucks usually return empty to the mines. With the industry nationalized, it would surely make sense if, on their return journey, they carried municipal compost to the farming districts through which they pass. If our criminally neglected waterways were restored to full use, compost could also be carried from city to farm in barges, the cheapest of all forms of transport. I think, therefore, that like most of the suggestions made in this chapter, it is merely a question of priorities. If the national need were recognized as being sufficiently great the means could be found.

If the municipal wastes of all our cities and larger towns were conserved and composted in this way they would yield about 3 per cent of our total humus requirements (Yield of finished compost from municipal wastes, 6,000 tons per annum, per 50,000 population. [See Technical Ref. Nos. 10 and 11.] Area of farmland, 32 million acres.) a perfectly safe proportion, always providing the composting has been properly carried out.

What then of the other 97 per cent? It is my firm belief that this amount is not beyond the capacity-of rural areas to provide if a proper balance between livestock and crops is maintained on our farms, and the abolition of waste made the rule in country as well as in towns. The burning of straw or roadside grass mowings for example would have to stop and a much fuller use than at present, made of bracken and seaweed. All these now largely wasted materials should be converted into humus.

The amount of finished humus that can be made on any given farm depends very largely on the farmer, but Howard cites a holding of fifteen acres at Lockerbie, Dumfriesshire, where the owner, Mr. Kenneth Crawley 'applies every year 10 tons of humus to each acre of his 14 acres of grass land, and 25 tons to his garden of one acre, i.e. 165 tons from the wastes of 15 acres. This means that each acre of this holding produces 11 tons of finished humus every year. An illustrated account of Mr. Crawley's small farm was published in the *Farmer's Weekly* of 10th April 1941.'

This, of course, is an exception, but it is not sufficiently realized that on a mixed farm in which well-managed, deep-rooting, four-year leys form part of the rotation, enough fertility can be built up in the four years of controlled grazing to carry over four years of arable crop production without any additional manures, compost, or fertilizers of any kind.

Rotational grass, coupled with sub-soiling (by wheel sub-soiler not deep ploughing) is the ideal method of maintaining soil fertility and could be introduced with advantage even in market gardens. (See below.)

I have purposely not dealt in detail so far with the cost of converting all farmyard manure and other wastes into compost (beyond the data given in Chapter III), because in the New Britain which I am picturing, in which our object would be to be mainly self-supporting and to draw labour away from the towns back to the country, the needs of the soil will take precedence over cash profit. But while, on this basis, the question of cost would be relatively unimportant, two points are worth noting in this connection.

First, that once the routine of composting is adopted, it falls easily into the general scheme of farming operations. Just as food for the livestock *above* ground must be grown, prepared and mixed, so the food for the livestock *below* ground--the soil population--must be prepared, even if, in this case too, special crops have to be grown to feed them--i.e. for composting. Where all hand labour is employed such a system would require one extra man per 100 acres. The practice, common before the war, of turning off surplus labour during slack periods will not, we hope, return. It is in these periods that the bulk of the compost can be made.

Secondly, against the actual cost of composting must be set, not only the saving of expenditure on purchased fertilizers, but the even greater saving, still assuming that this has been proved, that would result from the increased health and quality of the produce.

The whole of the foregoing arguments are based on the theory that the first duty of any nation is to feed its own people with fresh vital food, exports and imports representing true surpluses only.

If this principle were applied in this country it would entail a drastic redistribution of the whole population. A large proportion of those now engaged in industry for the export trade, would have to switch over to food production for the home market. It is my belief that such a policy will, in the course of time, be forced upon us, but there is no indication that any British Government is likely to adopt it voluntarily, so until sheer necessity brings it about, labour shortages will remain a problem, and mechanization, even of the compost heap, may be the only short term solution. Tools for this purpose are improving steadily. One of the most efficientis the Rapier Muck Shifter invented by Mr. Friend Sykes of Chute in Wiltshire, and manufactured by Messrs. Ransom and Rapier of Ipswich. In conjunction with open, or semi-open cattle yards, where the correct proportion of cellulose to dung is achieved at the outset in the manner described in Chapter III, this machine will assemble the compost heaps, turn them (at the rate of 200 tons a day) and finally fill the carts or wagons with the finished material. These machines at present cost from £500 to £1,000, according to type, no more than the price of a good tractor, thus they are within the reach of every big farm. Until cheaper tools are available the small farm could be catered for by contract machines, travelling from farm to farm.

Using this tool in conjunction with a simple mechanical spreader, consisting of an axle driven, flat, spinning plate towed behind the cart or lorry, Mr. Sykes has demonstrated that a farm's entire output of farmyard manure can be properly composted, carted to the field, and spread, for an all-in cost (including interest on capital and depreciation) of 2s. 6d. per ton. Thus the problem of cost, which has hitherto been the chief objection to large-scale composting, can, even in terms of orthodox accountancy, now be successfully solved. Whether, however, taking the long term view, so-called labour-saving devices do in fact truly cheapen production, when such questions as quality and soil conservation are taken into consideration, is at least open to doubt. H. R. Broadbent, Engineer to the London Passenger Transport Board, has pointed out that farm machinery, usually regarded as capital, should in reality be classed as imported labour. In an article appearing in the *Compost News Letter,* reprinted from *The Cross and the Plough* (1942), he puts this point of view as follows:

'It is common practice in comparing the output-per-man from a mechanized farm with that from a mixed farm using animal traction to say that a mechanized farm (In this quotation Mr. Broadbent is clearly using the term mechanized farm to denote the extensive stockless farm. There are of course such things as mechanized mixed farms.) is more efficient than a mixed, because the yield measured as output-per-man-on-the-farm is higher. This is true, at least for a time, because of the efficiency of mechanized traction and other machinery. Machinery is efficient in this sense of the term that a man with its aid can do more work in a given time than a man with hand tools or horse-drawn implements.

'Machinery is usually included as part of the farm's capital. It can, however, be regarded in a different light. It can be considered as concentrated labour imported on to the farm. If a direct comparison is to be made of output-per-man the machines should be considered as imported man-hours. Not only the machines, but the fuel, lubricants, and artificial fertilizers are all forms of concentrated imported labour. Each has had man-hours spent on its production, selling and transport. Indeed, the work of all men engaged in the whole line of production, selling and delivery, from the growers of the food for the makers, processors, salesmen and carriers to the accountant who finally balances his books, must be considered as a part of the importation and should be assessed as such in the form of man-hours imported on the farm. . . .

'The imported labour special to a mixed farm with animal traction (e.g. harness; provision of more gates and buildings) cannot weigh very heavily in the balance against that special to the mechanized farm.

'By how much would the mechanized output-per-man-on-the-farm be reduced if the concentrated imported man-hours were charged in that form to the mechanized farm? Would it fall below that of the mixed farm?. It is probable that no attempt has ever been made to find the answer. The difficulties are too great. Indeed, it may be argued that it is unnecessary to go to the trouble since the measure, output-per-man, is only one factor among many which are covered by a second measure, net profit.

'The money exchanged in all the various transactions, from the original payment for food for all workers in the chain to the final payment to the costs clerk, gathers together all factors under a common heading. If this is so, mechanized and mixed farms can be compared on a common basis, and if the mechanized farm shows a greater money return it is said to be more efficient.

'This statement is fundamentally unsound, for in the assessment of costs on the mechanized farm a vital factor is ignored. Little, if any, account is taken of the loss of fertility, the loss of capital from the soils which provided the cheap food for the sub-divided labour of machine production. . . . Machinery has been subsidized from soils which are now eroded, destroyed or in course of losing their food-producing value. Very little of this subsidy has as yet appeared in the cost of the machines.

'The argument that food from a mechanized farm is cheaper than from a mixed farm is without foundation. Its roots lie in the deserts of the world. . . .'

Unquestionably the restoration of mixed farming would be an essential feature of restored fertility. Captain Wilson is among those who consider the self-contained unit or balanced farm to be of vital necessity. He attributes the success of his fruit and vegetable growing at Surfleet largely to the contribution made to the market garden by the straw and livestock produced on the rest of the estate. (See evidence before Lord Justice Scott Commission.) Incidentally, this 300acre farm employs 33 men, 9 boys, 16 women and girls, and 11 working horses, and the value of the produce from it in the year 1941-2 (March to April) was £25,186, an indication of the labour absorbing capacity of intensive mixed farming.

So much for the contribution to soil fertility possible from our cities, our existing towns and villages, and our farms. But our town planning organizations picture the erection of many more villages both for housing rural workers and in the form of garden cities for urban workers. When these are built, a real chance will occur to break away entirely from the system of water-borne sewage, and thereby to contribute immensely to the amenities and health of these new communities. Many years ago a design for the building of a rural housing estate was put forward by Dr. L. J. Picton, whose suggestion merits serious consideration to-day

'A plot of four acres should be taken on the outskirts of a town and twenty houses built upon it. Suppose the plot roughly square, and the road to skirt one corner of it. Then this corner alone will possess that valuable quality "frontage". Sacrifice this scrap of frontage by making a short gravelled drive through it, to end blindly in a "turn-round" in the middle of the plot. The houses should all face south--that is to say, all their living-rooms should face south. They must, therefore, be oblong, with their long axis east and west. The larder, the lobby, lavatory, staircase and landing will occupy the north side of each house. The earth closet is best detached but approached under cover-a cross-ventilated passage or short veranda, or if upstairs, a covered bridge giving access to it. The houses should be set upon the plot in a diamond-shaped pattern, or in other words, a square with its corners to north, south, east and west. (See Fig. 7.) Thus one house will occupy the northernmost part of the plot, and from it, to the south-east and south-west, will run a row of some five or six houses a side, arranged in echelon. Just as platoons in echelon do not block each other's line of fire so houses thus arranged will not block each other's sunlight. A dozen more houses echeloned in a V with its apex to the south will complete the diamond-shaped layout. The whole plot would be treated as one garden, and one whole-time head gardener, with the help he needed, would be responsible for its cultivation. The daily removal of the closet earth and its use as manure--its immediate committal to the surface soil and its light covering therewith--would naturally be amongst his duties. A gardener using manure of great value, not a scavenger removing refuse; a "garden rate" paid by each householder, an investment productive of fresh vegetables to be had at his door, and in one way or another repaying him his outlay, not to speak of the amenity added to his surroundings instead of a "sanitary rate" paid to be rid of rubbish-such are the bases of this scheme.' (See Technical Ref. No. 12.)

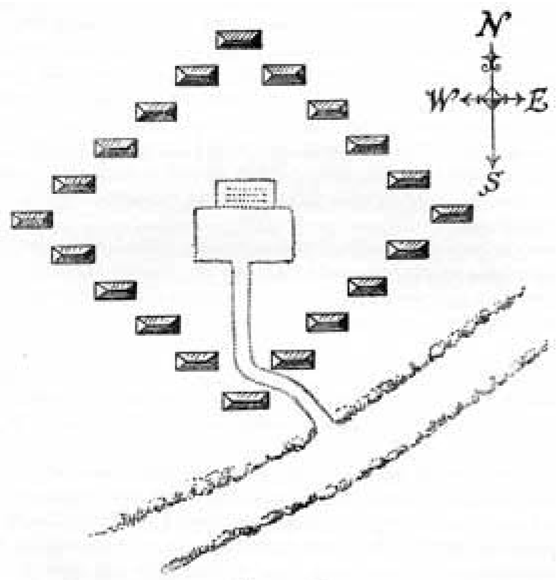

FIGURE 7

A still better method, and one which I feel sure Dr. Picton himself would have substituted had this plan been conceived more recently, would be, of course, to include pigs and poultry in the scheme and to manufacture humus by composting the night soil with the animal manure and other refuse of the community, rather than to apply it directly to the land. Besides being better for the health of the crops, and consequently the community, this would also enable finished compost to be supplied to the householders for use in their own gardens, for the houses ought to have private gardens in addition to the main communal one.

A very interesting example of rural sanitation carried out on the above lines has been successfully undertaken by Dr. Aubrey Westlake at his holiday camp in Hampshire. (See Technical Ref. No. 12.) There is no reason why the system should not be extended to permanent communities in the way that Dr. Picton suggests.

It is a particularly attractive idea that rates should be used to pay a gardener instead of a garbage man, and small communities such as this, could, by this method, be made self-supporting in vegetables, eggs, and bacon.

Another urgently needed reform is the opening of an entirely new line of agricultural research based on health rather than pathology, and on soil and plant ecology rather than on chemistry. There should also be legislation requiring fertilizers, before being put on the market, to be subjected to tests to determine their effect on the soil population in general, and on fungal activity in particular. There are already several organic 'manures' in existence that would pass such a test (e.g. bone meal, hoof and horn meal, guano, etc.) and at least one inorganic fertilizer (natural rock phosphate). Some people would also include basic slag, and there is no doubt that this slow-acting phosphate fertilizer is very much less risky than superphosphate, but there is still a division of opinion in respect to it. Some practical organic farmers and gardeners hold the view that even this fertilizer is ultimately harmful to the biological balance of the soil. It is certainly true that mushrooms disappear from meadows treated with it. Further research on this question is desirable. If and when means can be devised to augment available plant nutrients without at the same time upsetting the biological balance of the soil (and thereby also damaging its physical properties), so much the better, for the issue is not between humus and artificials, as such, it concerns the relative importance of the biological and chemical aspects of soil fertility: it is a question of the respective merits of a living soil and a dead one. If it is the life in the soil that is its most important property, then obviously we must stop killing it with lethal chemical salts. We must apply the rule of making Nature our teacher, to the inorganic as well as the organic strand in the life cycle. Nature supplies the mineral needs of plants in a variety of more or less complex ways: nitrogen through the nitrogen-fixing plants and soil micro-organisms, potash from decaying leaf remains, calcium from oak leaves, phosphates through the action of earthworms and deep-rooting plants and also through the combined action of humus and silicates. (Pfeiffer.)

These are a few examples of how the circulation of minerals is maintained in Nature. Rain also plays its part, absorbing both oxygen and nitrogen from the air as it falls. Mr. Secrett, the well-known market gardener, has made good use of this knowledge and has obtained most remarkable results by adding these elements to his irrigation water, by dissolving in it nitrogen salts, in a concentration which amounts to an application not more than 2 lb. to the acre, and by pumping into it 5 per cent of oxygen gas. The result of this last operation is to enable him to water his plants in a hot sun without causing scorching, and by applying his fertilizers only in solution and in the above 'homeopathic' doses he produces all the added growth stimulant usually expected from normal fertilizer dressings. It is difficult to believe that Mr. Secrett's method could be injurious to the life in the soil.

Colonel Pollitt in his booklet, *Britain Can Feed Herself,* (Macmillan and Co. Ltd., 1942), recognizes the need for vast quantities of farmyard manure to maintain fertility, but proposes, in addition, equally vast quantities of artificials, particularly sulphate of ammonia (one of the most lethal both to fungi and earthworms). He expresses the view that the more muck you use, the greater the quantity of artificial fertilizers required.

The reverse is certainly true; only large quantities of humus can avert the more serious effects produced by continued applications of large quantities of acid forming, water-soluble chemicals. In view of the evidence which has been presented here, it seems clear that great caution would be necessary in accepting his view. His whole approach to disease in stock and crops is one of accepting its control through the agency of poison sprays and sera. It seems to me that this approach is a tacit acceptance of a low standard of vigour, though he denies this. If the activities of soil fungi do play a vital part in proper nutrition, then clearly it would be unwise to adopt a programme such as he proposes without first testing the effect of these fertilizers on fungal activity and on the nutritive value of the subsequent crops. As stated earlier, this last can only be done satisfactorily by feeding tests, continued through several generations.

I think a word is due here on the vexed question of the use or misuse of fertilizers. One expert, writing in their defence as a supplement to humus, lists so many possible misuses that one is left with the impression that they are such a dangerous weapon in the hands of the nonscientist that their use should only be permitted under expert prescription, like poisonous drugs. Wrong balance between

N.P. and K., wrong quantity, wrong time of year, or wrong sort of weather at time of application, are all admitted to lead to serious consequences, and finally I read 'The use of fertilizers in the absence of adequate supplies of humus, is a misuse of fertilizers'. But in another place the same expert pleads that fertilizers are necessary because adequate supplies of humus are not available. (Donald Hopkins, *Chemicals, Humus and the Soil,* Faber and Faber, 1945.)

Both this view and Colonel Pollitt's are based on calculations of the amount of minerals removed from the soil by crops, farmyard manure also being valued on its chemical composition, but this is a highly unreliable method of estimating soil requirements. It ignores both the biological effects of F.Y.M. and also the selecting capacity of plants of which we know very little as yet. For example, tobacco ash is very rich in potash and it was assumed from this that the crop would benefit by applications of potash fertilizer. But on the plantation where this was tried a complete failure of crop resulted in every case except in those plots where no potash had been added! The oak, as has been mentioned, collects calcium, but the highest content of calcium is found in oak woods growing in calcium deficient soil. Where the trees are growing on limestone, the calcium content is much lower. Innumerable examples could be given of this curious behaviour in plants. Chemical analysis of soil is equally unreliable as a guide to treatment. The most conclusive demonstration of this took place on one of Mr. Friend Sykes' fields. When he purchased his Wiltshire farm, some account of which has already been given, there was one field of 26 acres of exceedingly poor quality pasture but which Mr. Sykes suspected of possessing considerable latent fertility. (See Chapter VII.) He had the soil analysed and it showed a very marked deficiency in lime, phosphate and potash. With the analysis was sent a fertilizer prescription, recommended for correcting these conditions. Sykes ignored it. He applied neither fertilizer nor muck, he simply ploughed up the field, pressed it, and sowed oats. He got 92 bushels per acre. He then sowed wheat, getting 68 bushels per acre. He followed this with a thorough summer till, after which the soil was again analysed. This time there was no deficiency in either lime or potash. Available phosphoric acid was still low, but the deficiency was less marked than at the first sampling. Once more no fertilizer or muck was applied, in spite of the expert view that a cereal crop could not be grown without a heavy dressing of phosphates. The field was sub-soiled and wheat was again sown, this time yielding 72 bushels per acre! This crop was undersown with rye grass and clover and the following year produced 2½ tons of hay to the acre in one cut. The field was again ploughed, and once more sown to oats, producing the record yield of 100 bushels per acre. By this time a third analysis showed no deficiency of any kind, a result confirmed by the improved crop yield.

This remarkable story is a very clear indication that the process of fertility in soil is not entirely chemical. What then was the explanation? Probably this: at one time this pasture had received plenty of dung, and the only true deficiency was oxygen. As soon as the field was thoroughly aerated the poor herbage was converted into humus, earthworms were given a chance to breed and get to work, and they and other soil organisms were thus provided with food to work on, so that they prospered and multiplied exceedingly, and as a result of their activities plant nutrients locked up in the lower soil levels were brought to the surface and converted into a form which the crops could use, and in quantities amply sufficient to leave a residue in the land after growing the crop.

This is the answer to the argument most frequently used by the orthodox school of thought, that under conditions of Western civilization the materials simply do not exist to treat all our agricultural land with compost in quantities sufficient to supply the known N.P.K. requirements of the crops we need to grow. We must therefore either be content to grow much smaller crops, or else supplement these three plant nutrients in the form of fertilizers. This argument is supported by the most impressive facts and figures, and the humus school is criticized fiercely for ignoring the proof of plain mathematics.

I think there is a real misunderstanding here and it is worth a digression to try to clear it up. The biological school (I prefer that word to the humus school) does not deny the chemists' estimate of the N.P.K. requirements of plants, nor does it claim that these needs are met by the N.P.K. content of the compost dressing which they consider sufficient. Their view is that the compost feeds the soil population, which if not discouraged by the presence of inorganic chemicals, multiplies to such an extent under this treatment that the by-products of its activities provide the balance of the N.P.K. needed by the crop, and in a much more balanced and health-inducing form. Four main ways are suggested as to how this service is performed: (1) through the stimulation, by growth-promoting substances, of the action of deep-rooting herbs, which can then fully exercise their capacity to collect minerals; (2) through earthworms making available the nutrients locked up in the subsoil (and chemists do not deny that these are to all intents and purposes inexhaustible); (3) by the association of certain soil organisms with the roots of plants for nutritive exchange; and (4) by the addition to the plant food supply caused by the decomposition of the innumerable dead bodies of the innumerable soil organisms as they complete their life cycle. The biological school ignores the chemist's mathematics, not because it despises mathematics, but because it is convinced that an operative, though at present unknown, numeral or set of numerals, is left out of his sum.

The biologist thinks in terms of life *being lived,* i.e. function, the chemist in terms of analysis. You cannot study life in terms of chemistry alone because to analyse life you have to destroy the very thing that you are investigating. When the chemist studies an egg he does so from without inwards, separating its constituents, from the shell to the germ, and analysing them. The most he can make of an egg from this approach, as Dr. Scott Williamson so well puts it (G. Scott Williamson, M.C., M.D., *Physician Heal Thyself,* Faber and Faber, 1945.) is an omelette, but when the biologist studies an egg, he does so from within outwards. His problem is to cultivate a chicken.

The chemist tells us that all forms of nitrogen are converted to nitrates before they can be absorbed by plants, and that there is therefore no difference between a nitrate derived from dung and one derived from sulphate of ammonia. The plant, itself, however, demonstrates that there is a considerable *functional* difference between the two. This applies also to the entities called vitamins. 'A vitamin held in the synthetic complex of a vegetable is not the same entity as a vitamin built up or reconstructed from a physical analysate--chemically pure. *Physical purity is biological sterility,* such a vitamin is a drug not a diet.' (G. Scott Williamson, M.C., M.D., *Physician Heal Thyself,* Faber and Faber, 1945.) The classic example to explain what is meant by functional difference is the fact that a baby's digestive ferments--pepsin and trypsin--if transferred from the baby to a test tube will there successfully digest steak and onions, but within the infant (living function) they can only digest its mother's milk.

The new line of research, therefore, must be the study of function, and one of its many branches should include experiments in connection with the growing of special weed and other crops for composting. There is little doubt that high fertility is stored in natural vegetation and that this is made available directly to other plants often without ever appearing in the form of detectable soluble nutrients in the soil itself. A good example of this is to be found in the tropics:

'As soon as the natural vegetation is destroyed the first thing that disappears, with astonishing rapidity, is soil fertility. This is particularly true of tropical forest soils in which nearly all the nutrient material is locked up in the vegetation or kept in continual circulation by the almost instantaneous decomposition of dead plant residues. The mineral soil contains very little plant food. The fertility that produces the most luxuriant plant association in the world is all contained in the vegetation itself; the soil is little more than a foothold for roots and a passageway through which nutrients are rapidly transferred from the dead to the living plants.' (Jacks and Whyte, *The Rape of the Earth.*)

Howard has given an interesting account of the part played by trees in making phosphates available to plants. (*An Agricultural Testament,* Chapter 9, Oxford University Press.) He tells how the available phosphate in the surface soil at Pusa in India is only about .001 per cent, the total phosphate also being abnormally low. Yet Pusa is known as 'the Garden of India'. 'The soil is highly fertile,' he writes, 'the region maintains a population of over 1,200 to the square mile: large quantities of seeds, tobacco, cattle and surplus labour are exported: there is no import of phosphatic manure of any kind. The facts relating to agricultural production flatly contradict one of the prevailing theories of agricultural science, namely, the need for phosphatic fertilizers in areas where soil analysis shows a marked deficiency in this element.'

In the course of his research work at Pusa, a detailed investigation of the roots of the trees 'which are so abundant all over the "Garden of India",' revealed that they 'comb the soil down to twenty feet for minerals, which are carried up to the leaves in the sap current, and finally reach the surface soil in the form of humus . . . the small amount of phosphate present is thus kept in effective circulation.' (A similar function is performed by earthworms in fertile soil. See Chapter VII.)

Sir George Stapledon and the late C. Alma Baker both introduced certain weeds alongside pasture. The latter called these hospital areas, and they included such weed herbs as yarrow, docks, sorrel, sow thistles and dandelion. These weeds, hitherto regarded as a nuisance, are now recognized as possessing special properties, some being valuable on account of their deep-rooting nature, and others for their richness in what are usually called 'trace elements'. There is no doubt that the whole question of our approach to weeds requires considerable modification. It is probably not accidental that the little weed 'eyebright' is known in Scotland as the 'mother o' wheat', and any compost-minded cultivator will rejoice at an abundance of chickweed appearing on his land.

All the foregoing reforms could be instituted with immense benefit to our soil without involving any violently revolutionary changes in land tenure. That some form of public ownership of land (not necessarily nationalization) (See *God Speed The Plough,* A. J. P. B. Alexander, also *Alternative to Death,* The Earl of Portsmouth.) will eventually come, I feel personally convinced, but this will only be justified if a National Food Service is thereby created, as part of a *true* Health Service. This would be something very different from the so-called Health Services of to-day which are, in reality, only Sickness Services.

I am fully aware of the dangers of increasing state control, but under existing political and economic systems it will always be extremely difficult (or so it seems to me) to prevent exploitation of soil or citizen while private profit remains the primary consideration governing the handling of food at any point between the soil and the consumer's table, and while propaganda, instigated in the interests of private profit, is allowed such power that it can create an artificial demand for an inferior article. The demand for white flour comes in this category. Before the war the majority of the people were hoodwinked, and the minority victimized, for even those who knew the value of wholemeal bread found it practically unobtainable. Pre-war brown bread was more often than not made from white flour with the bran added, but still minus the germ. People are beginning to know better now, and the demand for genuine wholemeal bread is greatly increasing, but no encouragement is given by the Ministry of Health--the reverse, in fact. A subsidy is given to the miller of national flour, but none to the miller of wholemeal, despite the fact that white flour yields saleable by-products and wholemeal does not. Stranger still, when in 1946, the decision was taken to introduce a whiter loaf, the Minister explained that this would result it a better quality loaf, while being only slightly less nutritious. 'What', as the Editor of the *Medical Press and Circular* aptly asked, 'is this extraordinary quality in a primary foodstuff that quite overshadows its nutritional food value?' I cannot refrain from quoting also the final paragraph of the same editorial. 'The apologetics indulged in whenever the national loaf is mentioned, and the implicit and persistent propaganda in favour of white flour, has led some of our nutritionists to the conclusion that the Ministry is in the hands of the milling interests. Perhaps it is; in any event one cannot fail to contrast its publicity with that of the much-maligned B.B.C. Speaking on the "Kitchen Front" a few days ago, our colleague, the Radio Doctor, said: "It's time white bread went the way of the tight corset, the ten petticoats, and the penny-farthing bicycle, and other anachronisms of the past." That is the sort of thing the Minister of Food ought to be saying but won't. It is perhaps natural that a Minister should be disposed to pander to the public, but it is unpardonable that he should attempt to mislead it.'

The excuse that flour will not keep if it contains the germ will not bear investigation. It is the practice of adding water to wheat before milling that prevents wholemeal keeping. This practice is said to be unavoidable because the wheat must be washed before grinding. Experienced millers, however, have proved that there are no technical difficulties in dry cleaning wheat, and many millions of tons are in fact dry cleaned annually. Whole wheat flour will keep long enough for all practical purposes if the grain is dried before milling. The bread made from this flour is excellent. If a foodstuff keeps indefinitely it is a sign that it has lost all vitality. It is sterile and dead. It is fortunate that working mills still exist in this country, to prove the truth of these facts, (Messrs. Clark & Leetham Ltd. of Hull, Mr. Prewett's at Horsham, Mrs. Horsefield's at Lindfield, Mr. Woods of Huby near Leeds, Mr. Gray Jones, Heath Mill, Worplesdon, Surrey.) for the big combine millers would have us continue to believe that wet cleaning of wheat is necessary, for the addition of water to the wheat adds greatly to their profits.

Howard has asked: 'This is the crux of the matter. Does the public exist for the profit of the millers, or is the real function of the millers the service of the public?'

The answer is of course: 'Under a system of private profit making--neither.' The primary duty of an industrialist is to his shareholders. It is not his fault, but the fault of the system, if in the process he has to gull the consumer. The case of flour has been given as an example, but it is by no means the only one. The advisability, therefore, of leaving the production of the prime necessities of life in private hands is very questionable. If these were publicly owned there would still be ample scope for private enterprise, and private capital, in the wide range of non-essential goods.

If, however, a form of nationalization of primary industries were ever adopted, decentralization would be absolutely essential. If public ownership involved centralized executive control from Whitehall, it would indeed be a case of out of the frying-pan into the fire. If the country has to choose between private ownership, and management from Whitehall, it would probably be wise to choose private ownership. In practice, when private ownership, whether of land or industry, is regarded as a trust, by an owner fully alive to his responsibilities, it probably gives better service to the community than any form of nationalization. The trouble is that no machinery at present exists for insuring that such standards shall be general. The result is that the conscientious private owner is often prevented from fulfilling his obligations, and carrying out what he knows to be his duty, because of the behaviour of his less scrupulous competitors. Thus if the people of this country are in future to be given health services as well as sickness services, some form of enlightened public control would seem to be inevitable.

I do not pretend to suggest what form this control should take, beyond saying that it should be in broad and reasonably elastic terms and that in so far as land is concerned the cultivator's occupation must be subject to good husbandry, always provided that he retains the right, should his trusteeship be called in question, to appeal, and to call witnesses, before a *truly independent tribunal.*

A merger between the Ministries of Health, Agriculture, and Food would be another step in the right direction, and would indicate a new and sounder attitude towards the primary needs of the people. Agriculture is a service; it is not, never has been, and never can be an industry. It is largely due to our error in calling it an industry that there has arisen the absurd idea that the interests of the town and country conflict. The town lives by the land no less than the country, and the country is equally dependent on the town. Both will eventually prosper or decline in proportion as their joint heritage, the fertility of their soil, prospers or declines.

It is tremendously important for the townsman to realize his dependence on the country. It had been truly said that the soil is the organic foundation upon which man's whole superstructure rests. 'Unless this organic foundation is sound . . . the superstructure built upon it cannot be sound. So it comes about that an urban civilization, which ignores the agricultural values, cannot itself be sound. Nor can any of the reforms, which it institutes for betterment within itself, be anything more than readjustments. They cannot be fundamental reforms. They can only result in fragmentary, not radical improvements. . . .' (G. T. Wrench, *Restoration of the Peasantries.* Daniel & Co. Ltd.)

I should like to see widely extended a system which has been organized by the Enfield Cable Company, and its associated factories. The management of this group has provided a country house where the men working in the factory can have one long week-end a year in addition to their annual holiday, and where they take their wives and children with them. The place is run (under the supervision of a resident matron) by these families themselves, and they keep it going by a small family payment coupled with their own voluntary labour in house and garden. Here, each week-end, among very many other advantages, complete family units from the city come into direct contact with the land. They also meet the land-workers who grow the vegetables for their factory canteen. The results have been quite dramatic from many points of view, but the aspect of the experiment that I want to stress here, is that these urban dwellers have come to realize their connection with the country, and the land. Their interest has been aroused; they now want to know how the food they eat is grown. The consumption of fresh, and even raw, vegetables has enormously increased in the factory canteen, and a noticeable improvement in health has resulted. This experiment has proved that the barrier between town and country is a quite artificial one and that, given the chance, the townsman will break it down for himself.

Contact between town and country should be encouraged on every possible occasion, and coupled with this the pursuits of farming should find a very definite place in our system of education. Farming as a profession should be part of the curriculum of all technical schools, and knowledge of our land and the fundamentals of good husbandry coupled with good diet should be part of the curriculum of every school, town or country. This view is beginning to be reflected in the management of more than one school of which perhaps the most interesting is St. Columba's, near Dublin. This public school for boys has built up, from small beginnings, a farming side which has now become an integral part of its educational scheme. The farm is now over 200 acres in extent, pays its way, is self-supporting (through the use of compost) and produces almost all the food for the college. An interesting account of this enterprise appeared in *Sport and Country,* March 1944 issue, from which the following quotations are taken.

'Those in charge of the farm believe that one of the secrets of their success is that the practical work was done first, and that that created a thirst for the theory of agriculture. The other secret is that all the work done is purely voluntary and done in spare time. . . . The health of the community generally has been unusually good, and the work and games have continued with additional zest. The main significance is, however, the fact that the boys are being educated to appreciate the rhythm of Nature and to understand intelligently her influence on the whole of life, while their powers of concentration and observation have increased. The experiment has also had the effect of welding the ordinary school activities into a community life, with the feeling that there is a contact between the School and the world outside.'

The land has been looked down upon hitherto as a career for the ordinary boy or girl, because it is said to have no future. By 'future' is usually meant a bank balance, but the function of education surely is to develop character, to produce vigorous, healthy men and women capable of forming a sound judgement on ultimate values, and of rendering their quota of service to the community.

The chief need in the world to-day, far transcending all others, is the need for a spiritual and moral revival involving the adoption of a different standard of values. If the farming profession were to be reorganized so as to fulfil its true function of serving the community, then the land could play an important part in this revival. There is a spiritual satisfaction in working on and for the soil, which few other callings provide, and the qualities which spring from that satisfaction can make a great contribution to the whole life of the nation, for it seems to me that of the many attributes that man needs in life, four of the most important are: (1) sufficient humility to recognize that a higher authority exists than himself; (2) sufficient self-confidence and purpose to undertake great enterprise; (3) sufficient patience to take a long-term view, and (4) the will to fight.

All four qualities are in the gift of the land. The life of the cultivator is one continual fight, but his adversaries (apart from such things as world markets, which should form no part of a farmer's hazard) are elemental things like storm, flood, and drought, so that--in contrast to human fighting--to win a battle is all triumph, and no bitterness: to lose it, no disgrace.

Watching things grow teaches patience, for do what you will you cannot hurry the seasons, and all farm planning must be long-term planning. Close contact with nature effectively counteracts any tendency to overrate the achievements of man. Living and working in the permanent presence of the three great mysteries of life--conception, birth, and death--breeds humility, yet, at the same time, the very nature of the work, concerned as it is with assisting the processes of life, bestows upon the worker the confident pride of being, as it were, an agent of God, Who alone can create that life. The net result is a balanced mind.

This gift of the soil; this health of spirit, mind, and body which a farm life can bring, should be made available to all, in the new Britain of equal opportunity. At present this aspect of life on the land is, with few exceptions, largely ignored in the teaching given in our schools. Even country-bred children are encouraged to think they are bettering themselves if they migrate to the cities, though frequently the jobs which they obtain there are no more remunerative, even on a cash basis, than those which they could have obtained on the land, and much less so in health and happiness. That it is possible for an intelligent boy, taking up land work, to rise in his profession was very clearly shown on the Higham estate, when this was under Captain R. G. M. Wilson's management. This consisted of 7,000 acres. Each of the farms comprising this estate was under the direct management of a foreman, and each group of two or three farms under a bailiff. Every one of these bailiffs and foremen rose from the bottom. All the personnel on the estate were imbued with consciousness of the constructive value of their work. The whole community, for the corporate spirit ran right through it, was a model of how large-scale farming should be carried on, whether the ownership be in private or public hands.

Another interesting enterprise in rural corporate development, and one deserving an equally close study, is that started by Mr. Rolf Gardiner in Dorset. (See *England Herself,* Rolf Gardiner. Faber and Faber, 1943)

I have now tried to indicate some of the ways in which proof of the connection between soil fertility and health would inevitably affect postwar reconstruction policy. I have of course been unable here to do more than touch the fringe of this very big question, but I hope I have succeeded in convincing you of the urgency of providing this proof, one way or the other, and in suggesting the lines upon which some of our future thinking should be done.

To sum up; first we must determine the factors governing healthy food, and having done so, no private interest must be allowed to prevent such food being made available to all sections of the public.

Secondly, our attitude must change towards refuse. It must no longer be considered as useless and objectionable rubbish, to be got rid of as cheaply as possible, but, on the contrary, as potential wealth.

Thirdly, we must educate our people to realize the interdependence of town and country, and that a nation's soil fertility is its most precious asset, and lastly, we must not overlook the implications of the definition of health arrived at as a result of the only scientific inquiry into the nature of Health in Man that has so far been made."

The biologists who conducted this inquiry came to define health as 'mutual synthesis of organism and environment', implying that 'a self-sustaining ecological balance underlies health' and that 'unless both man and his environment are obeying the biological law of mutual synthesis, there can be no health'.

Such a definition means that everything implied by the word vitality is as much a property of the environment as of the organism, since a *two-way* flow between them must take place. Health, they claim, 'is not a state at all. It is a process'." In other words, organism and environment, *both* living, must grow and develop together, *each* deriving its sustenance from the other. Thus to cultivate health one must first cultivate a vital environment.

In plant life, and to a lesser extent with animals, the organism's environment can be defined as the source of its food. Man's environment, however, 'is the source of his food, *and* of his experience--mental, social, and spiritual'. (See The Peckham Experiment, Pearse and Crocker. Allen and Unwin, 1943.) The biological law of mutual synthesis applies to his environment as a whole. The fruits of his experience enrich or impoverish the quality of the environment from which all his experience is drawn.

If one accepts this theory of mutual synthesis as a true definition of health-and these investigators offer cogent evidence in support of it--then it follows that any attempt to promote full health in the community must concern itself with maintaining the vitality of the *whole* of man's environment, from the soil in which his food is grown, to the 'soil' in which his spirit can expand. Success in such a venture cannot be achieved in a society dominated by the science of pathology, or the philosophy of materialism. It is for this reason that I have felt a postscript to this book to be not only relevant, but unavoidable.

CHAPTER X
POSTSCRIPT

Where there is no vision the people perish.
Proverbs xxix, 18.

Those of you who have followed my argument thus far, will have realized that my central theme has been our need for a 'sense of the whole'; a conviction that man's health and happiness cannot be secured if the whole balance of life is out of gear. 'Soil erosion has made a knowledge of the underlying principle of human ecology-the art of living together with animals, insects, and plants-one of the most urgent needs of mankind.' (Jacks and Whyte, *The Rape of the Earth,* see also *The Peckham Experiment, a study of the Living Structure of Society* [Ch. 1 and 2]. Pearse & Crocker, Allen & Unwin, 1943)

When attempting to write on a theme so vast as human ecology, it is impossible to leave the subject without making at least some mention of spiritual and moral values, for certainly there can be no health, in the sense of wholeness, if that vital side of man's personality is sick.

I have spoken of the need for a revolution in outlook with regard to agriculture, but that need is only a part of a larger need for a revolution in thought regarding ourselves, and our duties; to God, to each other, and to the State.

I believe that we are in the main alive to this need. If we are not, it is certainly not for want of being told by many far abler pens than mine. I do not pretend to any special qualifications for adding my quota to what has already been said and written on the subject, rather the contrary. I am merely one of millions of other ordinary citizens, who are at present thinking of these things, but since we are a democracy, I see no reason why only our distinguished citizens should be permitted the indulgence of doing some of their thinking aloud.

Nazi Germany has taught us what can be achieved when a whole people is imbued with an ardent faith. We believe that faith to be inspired by a conception of life which is essentially evil. But the fact that it is evil does not prevent it having the power to 'move mountains'. That is why tanks and planes and guns will not suffice to bring us victory unless, as a nation, we add to them the weapon of a faith, no less fervent and positive than that of our enemy's, though utterly different in kind. In the physical battle we have passed from the defensive to the offensive; we must do so also in the spiritual battle. Anti-aircraft guns alone would not have saved us in the Battle of Britain; we owe our deliverance to the offensive spirit of our fighter pilots. So with our faith. It is not enough that it should be *anti*-Nazi, it must also be *pro*-God.

You may ask, what have all these platitudes to do with humus? The answer is, a lot. Our attitude to the soil is dependent on our attitude to life in general. Lord Elton has pointed out (*St. George or the Dragon.* Collins, 1942.) that we shall not win this war unless we deserve to win it. Most assuredly we shall not win the peace unless we deserve to win it. We shall not win it, unless we are prepared to let our personal, and national, and international behaviour be ruled by the Christian ethic.

It is no good for us merely to hope for a better world after the war. Each one of us must work for it and sacrifice for it, and go on working and sacrificing for it. A better world is not like a manufactured article, which once you have made it, is finished, and can be enjoyed at your leisure. It is a living organism, and a pretty turbulent one at that. It has got to be managed, not driven. It is not an inanimate piece of mechanism like a motor-car that can be taken out on fine days, and locked away in bad weather. It is more like a colt that has to be exercised every day in all weathers, and skilfully handled, and fed and cared for before your own comforts are attended to, no matter how tired you are. That is one reason why health is so important. It is only the healthy that have enough surplus energy to combine the business of earning their daily bread with such energetic pursuits as colt breaking or new-world making.

This new world of ours is going to need all the energy we can bring to bear upon it. More even than we are giving to the war, because its demands will go on indefinitely. If we think it is going to be accomplished without effort and sacrifice, or that it can be brought about by governments without every one of us playing his part, we are heading for disaster. But if we are all to play our part effectively, we must know what we are working *for,* and here is the rub, because since the human race is composed of individuals, there are nearly as many views as to what constitutes a better world, as there are people. When these views are closely examined, however, it will be found that the vast majority differ only as to means, not as to ends. Therefore to achieve unity--and only unity will produce results--we must focus our ideas on the ends.

If our vision is fixed upon a genuine desire to build a Christian society, then all the 'isms' capable of functioning within the framework of a democracy will be able to co-operate, because from each will be removed the only stumbling block to co-operation, namely self-interest. If every individual were to accept the Christian ideal as the rule for his everyday behaviour, we could have our new world overnight, because this ideal involves putting the other fellow first. Capitalism and socialism could go hand in hand if employers always put the interest of the workers before their own, and if the workers always put the needs of their firm before their own comfort. Private ownership would be no brake on the progress of a State if private owners always put the needs of the community first. There would be no wars if every nation put the interests of every other nation before its own, and of course if everybody really did behave in this way, obviously nobody's legitimate interests would suffer.

Such an attitude of mind is not beyond the powers of human beings Individuals have achieved it in every age. During the depression several businesses went under because their owners refused to turn off labour, preferring to sink or swim with their workers, and there must be few people who have not experienced cases where a sense of responsibility for the welfare of others is so well developed in a given individual that it supersedes self-interest. I once knew a farm worker who never slacked unless he was on piece work. His attitude was that if he was on piece work and felt like going slow, he was free to do so, because no one suffered but himself, whereas to slack when he was being paid by time would be cheating. I knew another who refused a rise in wages on the ground that the farm could not afford it. Not the employer-but the farm. 'We can't afford it yet,' was the phrase used. Man is quite capable of holding such points of view, and of living up to them. The problem is to devise a system of education which will produce a nation of citizens among whom such an outlook is the rule and not the exception. To learn unselfishness, a man, or a nation, must first unlearn materialism. All our failures, as Lord Elton truly points out, have a common root--an age of materialism. 'It was materialism which lead us to mistake increasing comfort for progress, and materialism, elated by the rapid triumphs of science which persuaded us to overrate the capacities of pure intellect, divorced from every other human quality; with the twofold result that the goal of the "progress" which we worshipped proves to be catastrophe, and that many of those who lead us towards it have been men without judgement or courage. And so, since materialism is the root of all our troubles, it follows that the change that is at once most necessary and most radical is that we should cease to be materialists.' (*St. George or the Dragon.* Collins, 1942).

There are those who point out that no change of heart and no radical reforms, however desirable, are possible under our present financial and economic system.

I agree that money ought to be restored to its original function of being merely counters to represent real wealth, and that it never should have been allowed to become a commodity in itself. I agree that if it were so restored we might see an age in which plenty, security, liberty and leisure, went arm in arm, but I am neither qualified, nor was there space in this book, to discuss economic reform. There is one comment, however, I would make to those who consider economic reform the open sesame to Utopia, and it is this: No mechanism, however perfect, or necessary, that is purely materialistic will open that door. All reforms will fail that are not based on a foundation of spiritual values.

If our experience of the last twenty years has not taught us sufficient humility to realize that we are incapable of ordering our lives successfully in a Godless society, then one is tempted to wonder whether as a species we are worth preserving. In every activity, from the management of our soil onwards, we have regarded ourselves as self-sufficient, and in every activity that attitude of mind has led to disaster. We are the youngest of the world's species, and we have all the arrogance of youth. We have played havoc with the elaborate structure that was laboriously built up before we came, and now we find that we are not gods after all. We have been all-powerful in our destruction, but we cannot recreate the life we have destroyed.

Human ecology demands that we should think less of our 'rights' and more of our duties to all other living things, including each other. We must start again, with a new and better attitude towards life. Indeed we must in some cases relearn that life exists.

'The outcome and production, both in vegetable and animal bodies, have been hitherto considered so much under the prepossessions of chemical and mechanical philosophy, that the physiologists have entirely lost sight of life. . . . But unless we consider life as the immediate cause of all actions occurring in either animals or vegetables, we can have no just conception of either vegetable or animal matter.' (John Hunter, quoted from *The Discipline of Peace,* K. E. Barlow.)

In the *Rape of the Earth* Jacks lists certain attitudes of mind which determined the development of the prairies, and which led ultimately to their ruin, and to that of the settlers who held them. These attitudes are 'that Man conquers Nature; that natural resources are inexhaustible; that habitual practices are best; that what is good for the individual is good for everybody; that an owner may do with his property as he likes; that expanding markets will continue indefinitely; that free competition co-ordinates industry and agriculture; that land values will increase indefinitely; that tenancy is a stepping-stone to ownership; that a factory farm is generally desirable; and that the individual must make his own adjustments to calamity.'

Jacks goes on to say that these 'are the natural attitudes to adopt towards an extremely productive, lifeless natural resource, as the soil was supposed to be. The fact that the soil is very much alive and reacts violently against any treatment which weakens its vitality makes all the difference to the attitude to be adopted towards it.'

But these attitudes have not been confined to man's approach to the soil. They have frequently been his attitude to his fellow man. If we fail to realize our duties to each other, how can we be expected to recognize our obligations to the soil?

How is it that we have made such a mess of things? It is easy to see how the age of materialism led us to think we could get along without religion, but how did we come to think that we could get along in opposition to nature, of which even materialism recognizes that we are a part?

Dr. Wrench suggests that it is because a misunderstanding of nature's methods led us to believe that her law was one of competition, and of survival of the fittest. We certainly often talk, in a slightly patronizing way, as though we did better, of the 'prodigal waste in nature', but Dr. Wrench argues that there is no waste in nature, only return.

'The rule of return has been extruded by the dominant idea of the new era, which permitted and established the individual in the pursuit of his own interest without reciprocal duties or return. This freedom allowed the individual to pursue his own interest in his own way, compelled all to enter into competition with each other or groups with other groups. Those that succeeded best were pronounced the fittest.

'The biologists and scientific publicists of this era came to see a similar picture in nature. They saw nature as producing a million seeds, of which a few became individuals. They saw these individuals competing together and they termed the surviving individuals the fittest. The whole of nature was regarded as a scheme to secure the end-result of these fittest individuals. This it was, that constituted nature's aim and meaning. The rest was ignored as failure.

'But in nature there are no life-failures: the seeds which fall upon the ground and do not become individuals do not fail in the recurring wheel of life. They still fulfil their part. (Dr. Pearse (*Peckham Experiment*) has suggested that this re-absorption into the environment of apparently surplus individuals may be nature's method of modifying and developing the environment so that from it new or modified forms of life can emerge. If so, without such re-absorption there could be no evolution.) The tree that is surrounded by fallen seeds in spring, in course of time gathers some of these elements of life back into itself. Other elements either enter into the verdure or more immediately into the bodies of birds, insects, or animals. The elements of life, whether as fallen seeds, leaves, or the tree itself migrate into other forms of life.... It is man, not nature, who wastes in this cycle of life. It is he who causes soil-exhaustion by taking and not returning.' (*Restoration of the Peasantries*. C. W. Daniel & Co. Ltd., 1941.)

It seems then, that we must recognize that to be 'fit' in the sense of being a successful competitor against nature, is not sufficient to ensure survival. In fact the greater our apparent success in such a competition, the more surely are we sealing our doom. Elsewhere in the same book Dr. Wrench expresses the view that 'The chief problem which faces the next generation, the generation, that is, for whom we are presumably seeking peace, is that of bringing agriculture and industry into some sort of balanced relation. It appears to me that this can only be done by a revolution in thought, as considerable and as important to the future as that which occurred under the aegis of Newton, Descartes, and the other thinkers, who established the philosophical world of materialism. Our world must be conceived as a kingdom of life, wherein the performance of vegetation is recognized and respected. Agriculture and industry must each be recognized as varying modes of human interference in this kingdom. Man himself is to be recognized as a free subject, but his freedom is held in fee and the price of it is his allegiance to, and participation in the performance of the total ordered structure. The balance which remains to be struck between agriculture and industry is demanded, not by the competition of these two activities, but by the requirements that all man's manipulations shall represent an effort to co-operate with the major performance of life.'

Much the same view is expressed by Jacks and Whyte as follows: 'The efforts of agricultural peoples, if they are to survive, must be directed to the repair and maintenance of the vegetation of their hills and valleys. But efforts of this sort are very different to those to which they have been accustomed. In the first place, *the whole of the community must share in this endeavour,* (Italics mine [author]) because the geographical unit is the unit of administration. In the second place, the returns obtained will not be immediate. Not only is the expenditure of their labour to be charged to capital account, but the resulting capital is still not productive of commodities. It is true that the organization will in time somewhat increase surpluses, but the periods of time are long and the increase of surpluses slight. Accordingly, large sums of money and considerable expenditure of labour must be laid out unproductively. The outcome of such undertakings is fertility and not produce. Their purpose is to promote and maintain the achievements of vegetation so that these may continue to provide the conditions in which man himself can live.' (*Rape of the Earth.)*

Here is the task then, which faces mankind. A task as urgent as the winning of the war, and one in which the spur to labour is the same--self-preservation, and the survival of civilization.

Man is born selfish, but in moments of great national crisis he is capable of sinking utterly his own interests for the good of the community. How often do we hear it said that if only we were prepared to put into the constructive arts of peace, the united effort in courage, sacrifice, labour and money, that we are prepared to exercise in the destructive art of war, we should be assured of our better world.

One reason why we can rise to such heights in war, seems to be that only when we are threatened by destruction from outside do we recognize that our own interests are ultimately bound up with those of our fellow countrymen, and thus a common danger brings unity of effort.

If it is a common danger that is needed to produce co-operation and unity, then the whole world shares a common danger in the disappearance of its soil. At present we are not awake to that danger. Our attitude to it is very reminiscent of our attitude to the Nazi menace in the pre-war and early war periods. It took the rape of Europe to make us fully alive to the Nazi menace. Must mankind wait until famine overruns a whole continent before he realizes the danger that threatens him from encroaching deserts? If so, our awakening will be an even ruder one than it was in 1940. Should this happen, peoples will be faced with two alternatives. Either there will be a scramble for what little remains of the habitable globe, or else once more, there will be a 'United Nations'--this time of the whole world---to work shoulder to shoulder to meet the common peril, in the labour and sweat of self-preservation.

Which choice the nations will make will depend on the extent to which they have succeeded in abandoning materialism. But need we wait until man is threatened with imminent extermination? How can we avoid such a calamity? Only, I think, by educating the next generation to believe in other gods. The false idols of comfort and money must be dethroned, and the Christian God of service put in their place. Service to God, service to our soil, service to each other, and, *through each other,* to the community and the world. That is the order in which they should be taught; in any other, there would always be a danger of falling into the Nazi idolatry, of deifying the State.

Inherent in this education for service would be the teaching of good citizenship. This once more involves the application of the law of return; the acceptance of the principle that all rights carry corresponding duties. We have seen that to take from the soil without return is a form of brigandage which ends by robbing ourselves. To accept privileges from the State, which means the community, without making payment in service is the same kind of theft, for the State belongs to its citizens, and the citizen is a part of the State.

To think that, in a democracy, the interests of the State and its citizens can conflict, betrays the same confusion of thought as that responsible for the fiction that the interests of town and country conflict, or that man can 'conquer' nature. The State is but the sum of the individual citizens that compose it, and the Government, the freely chosen directorate of their corporate activities. This should be a truism, but the almost universal tendency is to see the State and the Government, not as a part of ourselves, working in a symbiotic partnership, but as some quite independent and outside entity, there for the purpose of protecting *us,* doing things for *us,* or else (according to our income level) taking *our* money. This attitude is prevalent even among otherwise responsible and public-spirited people.

I know a top farm hand who has recently entered the ranks of the new income-tax payers. Like many of his fellows in industry, he tries to keep his earnings down because he does not want to 'give' his money to the Government. But since loyalty to the soil has always been his guiding rule, he does not, like his city prototype, refuse to work overtime; he works as many hours overtime as ever, but he refuses to be paid for them!

See what twisted reasoning is here; he will work for nothing, or rather he will freely give his services to the land, but not his money to the community, even though he too would ultimately benefit financially. He recognizes that the land is a part of him (though he has probably never thought about it), but he cannot see any connection between himself and the Government. It never occurs to him that, as members of a community, when we contribute to its central funds we are merely paying for our share of the privileges which we enjoy; that we are, in fact, exchanging cash for goods or services.

Education is surely at fault here. In future citizenship must be taught as something positive, and vital. The relationship of the individual to the State should be one of complete mutualism. Citizenship should only be granted on that basis. A period of service to the community should be the price of entry into the privileges of membership.

I believe that, in this country, compulsory service, whether military or civil, is too alien to our national character to be readily accepted in peace-time, but on the other hand I believe a system would work in which full citizenship, with its political rights and other privileges had to be earned.

Under this plan every boy or girl would have to pass some form of citizenship test to show that he or she had some knowledge of the workings of the democracy in which we live, and the commonwealth of which that democracy is a part. To qualify, they would also have to give at least six months free service to the community, whether in the armed forces or merchant navy, on road or farm, in mine or factory. When possible, town dwellers should be directed for their service to the country, and vice versa, thus would the sense of the interdependence of all citizens be kept alive.

Citizenship of such an organization as the British Commonwealth, or the larger commonwealth which may some day come, is worth working for. Any national who did not think it worth his while (and there would, I think, be very few) to qualify for citizenship, would do the community little good as a citizen. It would be better in every way if he remained a non-citizen resident, protected by the common law, but without franchise.

When a new generation has arisen, taught to have a living faith in the Christian ideals, to value and conserve its soil, and to put service before comfort, then not only will our land have citizens worthy of it, but it will also be a land of happy contented people, for it is important to remember that happiness is a by-product. It is, moreover, a by-product of activity, not of ease. It cannot be found ready made. Nor can it be fashioned out of those things usually covered by the term 'a higher standard of living'--material comfort, more leisure, more money, more gadgets. Important as they are, these are static things. Happiness, which must not be confused with pleasure, results only from those activities which develop personality and character. It can be achieved in varying degree through the physical exertion of work or play, all though the mental exertion of acquiring knowledge, through the spiritual exertion of creative effort, through the exercise of skill, through service; perhaps most of all through service. If we seek happiness as an end in itself, it will elude us; if we make service our aim, happiness will follow automatically. This is as true for a nation as for an individual. We shall never succeed in building a 'better and happier world' until we recognize it. When we do, we shall discover that we are on the high road to building a Christian society, for happiness through service is a creative force of unlimited power for good. In its atmosphere ecology-the most needed of all the sciences-could flourish, and could in time help us to become truly aware that everything in Heaven and earth is but part of a single whole. Then for the first time in many a century could we justifiably claim to be entering on an age of progress.

TECHNICAL REFERENCES

Reference No. 1, Chapter I

EXTRACT FROM P.E.P. REPORT ON BRITISH HEALTH SERVICES (1936)

A

Many of the costs of ill health cannot be measured in money. 'The subjective element in the endurance of pain and sickness cannot be estimated. It is impossible to say what contribution might in happier circumstances be made to the community by that regrettably large body of persons who 'enjoy indifferent health', whose energy is all absorbed in struggling through the daily round.

But the cost of treatment and maintenance of sick persons is susceptible to measurement in money; it would also be possible, if data were available to put a money value to the work lost through sickness with absence from regular employment.

After considering these costs it is appropriate to take stock of expenditure on the prevention of ill health.

The figures in the following section refer, unless otherwise stated, to Great Britain.

The total number of working weeks lost by persons claiming National Health Insurance sickness benefit was 29 millions in England and Wales in 1933, and in Scotland 2.8 millions in 1936. This excludes most illnesses of less than four days' duration, sickness for which benefit was not claimed, and the sickness of persons working on their own account or earning more than £250 a year. Thus it probably represents well under half of the total loss. Yet if the average wage of the persons included in the above figures were £2 a week the money value of the work lost would be over £60 millions a year. At a very moderate estimate the money value of all work lost cannot be less than £100 millions a year. This estimate takes no account of the dislocation in industry caused by sickness absence, but the loss is partly offset where the work of the absentees is done by persons who would otherwise be unemployed.

B

The items in the annual cost of ill health which have been estimated above may be summarized as follows:

	State and State insurances £ millions	Voluntary and private enterprise £ millions
Doctors	12	38
Medicines		25
Dentists	2½	7
Other ill health services	41½	22
Insurance cash payments including administration)	30	7
	86	99
	185	

This sum represents about one-twenty-fifth of the national income.

Reference No. 2, Chapter II

DISEASES FOUND IN RATS OF COONOOR AS A RESULT OF FEEDING THEM ON FAULTY HUMAN DIETS

Lung diseases: Pneumonia, broncho-pneumonia, bronchiectasis, pyothorax, pleurisy, haemothorax.

Diseases of the ear: otitis media or pus in the middle ear.

Diseases of the nose and accessory sinuses: sinusitis. Diseases of the upper respiratory passages: adenoid growth. Diseases of the eye: conjunctivitis, corneal ulceration, keratomalacia, panophthalmitis.

Gastro-intestinal diseases: dilated stomach, gastric ulcer, epithelial new growths in the stomach, cancer in the stomach (in two cases only), duodenitis, enteritis, gastro-intestinal dystrophy, statis.

Diseases of the urinary tract: pyonephrosis, hydronephrosis, pyelitis, renal calculus, ureteral calculus, dilated ureters, vesical calculus, cystitis, incrusted cystitis.

Diseases of the reproductive system: inflammation of the uterus, ovaritis, death of the foetus in utero, premature birth, uterine haemorrhage, hydrops testis.

Diseases of the skin: loss of hair, dermatitis, abscesses, gangrene of the tail, gangrene of the feet, subcutaneous oedema.

Diseases of the blood: anaemia, 'pernicious type of anaemia', Bartonella Muris anaemia.

Diseases of the lymph and other glands: cysts in the sub-maxillary glands and accessory glands in the base of the tongue, abscesses in the same, and occasionally also in the inguinal glands, enlarged adrenal glands, atrophy of the thymus, enlarged mesenteric, bronchial and other lymph glands.

Diseases of the nervous system: polyneuritis.

Diseases of the endocrine system: lymph-adenoid goitre, and very occasionally, haemorrhage into the pancreas.

Diseases of the heart: cardiac atrophy, occasionally cardiac hypertrophy, myocarditis, pericarditis, and hydro-pericardium. 'Oedema'.

Reference No. 3, Chapter III
COMPULSORY PASTEURIZATION

In spite of the recent deputation to the Minister of Food by a group of doctors said to represent the medical profession, this controversial subject remains one upon which medical opinion is sharply divided. There is an equally sharp division in the milk industry. The question is one which is usually debated with considerable heat on both sides, the ordinary milk consumer may therefore care to see the pros and cons stated side by side.

The two main groups in favour of compulsory pasteurization are some unknown proportion of the medical profession, let us say half, and all the big milk distributors.

The attitude of the doctors is obviously disinterested. They say that safe milk is better than so-called clean milk, and that compulsory pasteurization would abolish tuberculosis of bovine origin, said to cause 2,000 deaths a year. They consider that this would far outweigh any possible disadvantages.

The attitude of the big milk distributors is less disinterested. Under our present system by which the milk for our cities often travels long distances, it is obvious that only pasteurization would prevent it being sour by the time it reached the customer. But this is no part of the argument, for in cities most of the milk is already pasteurized. (A service agriculture--see Ref. No. 9--would obviate this necessity.) The support given by the distributing combines to the call for compulsory pasteurization springs from the fact that this would put the small distributor, including the producer retailer, out of business, for they could not afford to instal the necessary plant. A further point is that pasteurization enables the big distributor to sell milk several days old without the customer being aware of the fact. Milk in towns left unsold one day, usually goes out on the round the next.

The main groups opposed to compulsory pasteurization are the other half of the medical profession, and all producer retailers. Here again the attitude of the doctors is quite disinterested, they too want to abolish tuberculosis, but they do not think pasteurization is the way to go about it. They point out that the incidence of tuberculosis is higher in the big towns where milk is already pasteurized, than in the country where it is usually taken raw. They say that it is insufficient milk, and other protective foods which induce the liability to tuberculosis whether of bovine or other origin; that both the vitamin and calcium content in milk are injured by pasteurization, that raw milk in adequate quantities is the best protection we have against caries of the teeth, and other evils of malnutrition, that the lactic acid bacteria in milk, which are beneficent, and which attack disease organisms, are killed by heat, so that after pasteurization milk is a perfect breeding ground for any contamination that may reach it after delivery to the customer, and that in short, compulsory pasteurization would produce more evils than it would cure.

The attitude of the producer retailers, like that of the big distributors, cannot be free from an element of self-interest since compulsory pasteurization would put them out of business, but many of them also argue, with a good deal of justice, that theirs is the class of producer that has done most to improve standards of milk production, and that the right way to get safe milk is to have clean milk from healthy cows. They point out that by far the commonest source of tubercle bacilli in milk is manurial contamination, because the great majority of tuberculous cows have intestinal tuberculosis. A tuberculous udder is comparatively rare, and in a well-managed herd should be quickly detected. Compulsory pasteurization would have the effect of eliminating the producers who do not sell contaminated milk and would leave untouched the dirty producers. For raw milk must be clean or it goes sour, only pasteurization enables the dirty milkers to get away with it.

Summing up these arguments it seems to me that pasteurization can never be a good thing in itself. It should be regarded even by its advocates as the lesser of two evils. The necessity for it, where that exists, is a confession of failure. The aim should be to abandon the practice just as soon as the need for it--unhealthy cows and dirty methods--can be eliminated. In the meantime those producers who *have* eliminated these conditions should be exempted from any compulsory order, while at the same time penalties for dirty milk production should be very severe. For there is no excuse for it. I have proved this. At a time when the only water supply on the farm was an open moat I entered a county clean milk competition. With only this moat water to use for washing the cows and the dairy utensils, and only a home-made sterilizer consisting of a perforated container stood over a farm copper, I not only won the competition, but my average bacterial count per c.c. was under 5,000, sometimes under 500 (the maximum allowed for certified milk--the highest grade--is 30,000). For many years I sold my milk retail, in a town over fifteen miles away. I guaranteed its keeping quality for forty-eight hours in the hottest weather. Not once in a blue moon did I have to replace a pint under this guarantee. Milk kept back for testing was often sweet over a week old. My milk was frequently ordered by local doctors for ailing babies, unable to digest other milk, or patent foods. I have their testimony that it saved many babies' lives. This taught me that really healthy, safe, raw milk can be produced by any farmer who cares to take the trouble. When produced in this way I have no shadow of doubt that it is in every way preferable to pasteurized milk.

Reference No. 4, Chapter III
THE NEW ZEALAND COMPOST BOX

The Indore process was originally devised for dealing with comparatively large quantities of wastes. . . . In gardens where the quantity of wastes is small two minor difficulties are often encountered. Wind and rain interfere with the rate of fermentation. Wind lowers the temperature of the outer layers of the heap and also removes large quantities of moisture. Excessive rain, by making the whole mass sodden, interferes with the air supply. Low temperatures, dryness and shortage of oxygen are all harmful factors, because they impede the work of the fungi and bacteria engaged in the synthesis of humus. These work best at temperatures ranging from 150° to 90° F., when the heap is moist and when there is ample oxygen.

These difficulties can be overcome by the use of the New Zealand box. This has been devised by the Auckland Humic Club for use in the gardens of New Zealand and works well in this country. A suitable box can be made as follows:

Materials required. Six 3 ft. 3 in. lengths of 2 in. by 2 in. for uprights. Twenty-four 4 ft. lengths of 6 in. by 1 in. board for the four sides of the box. The unplaned timber should be oiled with old motor oil to preserve it, but tar or creosote should not be used.

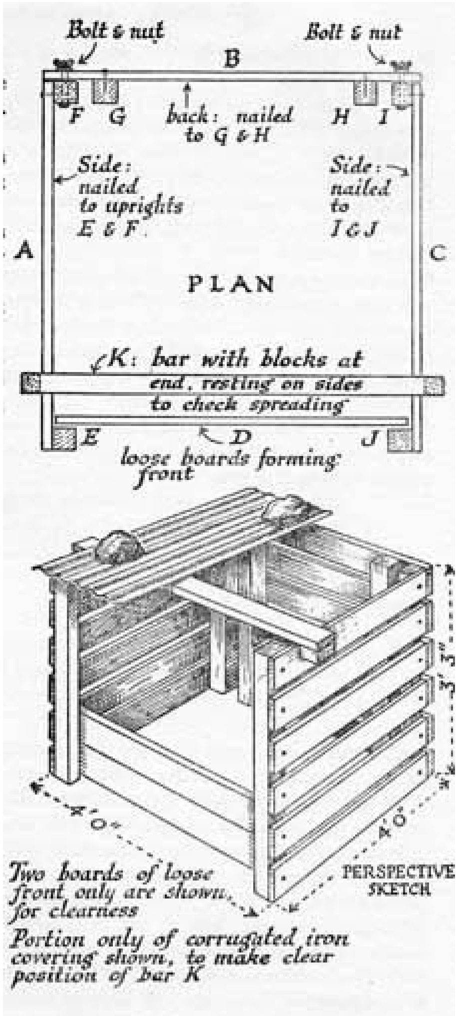

FIGURE 8

E. F. G. H. I & J are the uprights (each 3 ft. 3 in. long).

A, B & C are the sides (each consisting of six boards, each 4 ft. x 6 in. x 1 in., nailed to the uprights half an inch apart to allow ventilation).

D is the loose front (six boards).

K is the bar, provided with a block at each end, to sit on top of the sides A & C to stop them spreading.

The box (see Fig. 8), which has no bottom, stands on the ground, so that it can be moved to a new site alongside. First nail the side A to the uprights E and F. Next nail the back B to the uprights G and H. Next nail the side C to the uprights I and J. When nailing the boards on to the uprights leave a half-inch gap to provide ventilation. The three sides of the box are now complete. The sides and end are bolted together by means of four bolts-each fitted with two washers and a nut which unscrews on the outside-which join the back B to the uprights F and I. The front D is made up of loose boards 6 in. by 1 in. slipped behind the uprights E and J as the heap rises. To prevent the sides A and C from spreading outwards use a wooden bar K 2 in. by 1½ in. with two wooden blocks (3 x 2 x 1½ in.) as indicated in the ground plan and elevation below. (See Fig. 8.)

When the box has to be moved to a new site, remove the loose boards and the four bolts and re-erect the box in a fresh place.

Making the heap. Having made the box, throw your mixed vegetable material (broken or cut up if necessary into lengths a few inches long) into it as it comes to hand, together with one-third the volume of manure, mixing the wastes and manure as the box is filled. The proportion by volume of mixed vegetable wastes to manure should be three or four to one. All garden or unused kitchen waste may be used including weeds, lawn mowings, crop residues, leaves, hedge clippings and seaweed when available. Where animal manure or soiled animal bedding are not available, substitutes such as dried blood, hoof and horn meal, or fish manure may be used, but in these cases only a very thin film, about a quarter to an eighth of an inch thick, is needed for every six-inch layer of vegetable waste. If none of these substitutes can be obtained the heap can be kept moist--not wet and sodden--by means of bedroom slops. Animal wastes in some form are essential. Sprinkle every six inches of the mixed vegetable and animal matter with a layer, about one-eighth of an inch thick, of earth (mixed with wood ashes, powdered limestone or chalk or slaked lime if available). A thin film to neutralize excessive acidity is all that is needed; too much earth hinders the ventilation of the mass. Next water this sandwich with a hose fitted with a rose, or with a watering-can, until it is wet but not sodden. Continue this building and watering process until the total height is reached. Rain (which is a saturated solution of oxygen) should be used whenever possible instead of the rose to keep the heap moist. After the box is half full make and maintain three vertical ventilation holes, one in the middle and one near each side, by thrusting a light crowbar or stout garden stake into the heap and working it from side to side. The holes should go as far as the earth underneath the box.

The box should be protected from rain and sun by means of two pieces of old corrugated sheeting, each 58 in. x 26 in. These are kept in position by means of bricks or stones.

Two things must be watched: (1) An unpleasant smell or flies attempting to breed in the heap. This ought not to happen and is generally caused by over-watering or want of attention to the details of making the heap. If it occurs, the heap should be turned at once. (2) Fermentation may slow down for want of moisture, when the heap should be watered. Experience will teach how much water should be added when making the heap.

Turning the compost. Provided due care is taken in filling the box, only one turn is necessary. After six weeks or so the contents should be moved to a convenient site outside the box, watered if needed to keep damp, and allowed to ripen for a month or six weeks under a suitable cover (such as old sacks or an old piece of tarpaulin). No ventilation vents are needed in the ripening heap. The compost which weighs about a ton is then ready for use and should be applied to the garden as soon as possible. If it must be stored, it should be kept in an open shed and turned from time to time.

(*Adapted from a leaflet issued by the Humic Compost Club,*
Auckland, New Zealand. Dr. G. B. Chapman, President.)

See also *Composting Pig Manure* by J. W. Scharff, M.D., issued free as *Advisory Leaflet No. 7* by The Small Pig Keepers' Council, Turville Heath, Henley-on-Thames.

Reference No. 5, Chapter IV

A

(1) There is conclusive evidence that Wareham soil contains 'toxic' factors of biological origin that operate as inhibitors to fungal growth. (See Neilson-Jones, *Biological Aspects of Soil Fertility,* Cambridge University Press.) (2) In laboratory culture the inhibiting action has been directly observed upon a number of soil-borne and air-borne fungi, including proved mycorrhiza formers as well as other species that form pseudomycorrhizal associations with tree roots. So far as is known the effects produced are not lethal, but are evidenced as more or less complete inhibition of mycelial growth and of germination of spores. There is evidence of differential susceptibility among the fungal species observed. (3) The condition of biological inertia thus brought about in the soil is manifested in many ways. It leads to the formation of a substrate unfavourable to root growth and affects mycorrhiza formation directly by inhibiting mycelial activity, although suitable mycelium may be present in the neighbourhood of roots. Reduced fungal activity as compared with that in non-toxic soils of similar type is confirmed by direct microscopic examination; fungus mycelium is relatively scarce and there is a notable absence of the peritrophic fungus flora often conspicuous about roots and mycorrhizas. These characteristics greatly simplify observation of the mycorrhizal relationships in Wareham soil: there are present only few fungal species that form mycorrhizal association with the roots of pines and other conifers, and there is a notable absence of activity on the part of soil fungi known to cause parasitic or pseudomycorrhizal attack on roots; the task of isolating mycelia of the fungus associates from individual mycorrhizas is thereby made comparatively easy. (Rayner, *Forestry,* 1941.)

B

TABLE I

Figures represent percentage values in dry compost)

	C5	*C1*
Potassium oxide (K_2O)	0.75	1.04
Phosphoric acid (P_2O_5)	2.80	0.77
Total nitrogen	4.64	3.33
Ammonium salts	0.21	absent
Nitrate nitrogen	0.15	0.43

It was calculated that the two composts, C 5 and C 1, each applied at the rate of 10 lb. per square yard--the amount used in field experiments--would supply to a crop available nutrients as shown in the following table.

TABLE II

Available nutrients in pounds per acre contained in compost applied at the rate of 10 lb. per square yard.

	N	*K20*	*P205*
C 5	71	14	40
C 1	16	65	17

The amount of salts supplied to the pots in Series 3 and 5 receiving equivalent nutrients were calculated from figures kindly supplied by Dr. Robertson of the Macaulay Institute for Soil Research, as shown in Table III. The calcium content of C 5 and C 1 were also calculated, the values found representing approximately 8 gm. and 4 gm. of lime (CaO) per 250 gm. of dry compost respectively. As in pot experiments generally, the amount of compost added to the experimental soil was at the rate of one part of compost to three parts of soil, this being regarded as roughly comparable with the 'dilution effect' obtained by the dressings used in the corresponding field experiments. On this basis, the dry weights of composts required for each experimental series was 231.5 gm. of C 5 (oven-dried) and 240.8 gm. of C 1 (oven-dried) per 12 pots,

TABLE III

Available nutrients per 250 gm. compost (air-dried)

	N. gm.	*K20* gm.	*P205* gm.
Series 3 (salts of C 5 compost)	1.45	0.30	1.00
Series 5 (salts of C 1 compost)	0.38	1.30	0.35

or roughly 20 gm. per pot. Using the values for available nitrogen, potash, and phosphoric acid set out in Table III there will be required, therefore, for the 12 pots of Series 3 (receiving equivalent salts of C 5) and for the 12 pots of Series 5 (receiving equivalent salts of C 1) the following amounts:

	Series 3 (C 5 salts)	*Series 5 (C 1 salts)*
N	1.34 gm.	0.35 gm.
K20	0.27 gm.	1.25 gm.
P205	0.96 gm.	0.33 gm.

The nutrients were given as ammonium nitrate (NH_4NO_3), potassium sulphate (K_2SO_4 anhydrous), and sodium disphosphate (Na_2HPO_4 anhydrous), as supplied by British Drug Houses Ltd. for analytical purposes, there being required for the 12 pots of Series 3, 3.83 gm. of NH_4NO_3, 0.49 gm of K_2SO_4, and 1.92 gm. of Na_2HPO_4, and for the 12 pots of Series 5,1.03 gm. of NH_4NO_3, 2.3 gm. of K_2SO_4 and 0.66 gm. of Na_2HPO_4. These salts were used in two solutions applied at the rate of 25 c.c. per pot as follows:

	Solution for Series 3	*Solution for Series 5*
NH_4NO_3	12.8 gm.	3.4 gm.
K_2SO_4	1.6 gm.	7.6 gm.
Na_2HPO_4	6.4 gm.	2.2 gm.
Distilled water	1,000 c.c.	1,000 c.c.

It will be observed that the equivalent amounts of nitrogen and phosphoric acid are relatively high in compost C 5, and the equivalent amount of potash relatively high in compost C 1. By similar calculation from the figures supplied for the lime content of C 5 and C 1, each pot of Series 3 required 1.1 gm. (1 gm.) of $CaCO_3$ and each pot of series 5 required 0.56 gm. (0.6 gm.) of $CaCO_3$.

The composts were mixed with the soil at sowing, and the equivalent salt solutions given in one dose per pot when the seedlings were emerging from the seed-leaf stage and making active root growth. The amount of solution was just sufficient to moisten the soil without draining through it. The calcium carbonate supplied was powdered uniformly on the surface and worked in with a glass rod at the time of sowing.

C

GROUP I. DRAINAGE RETURNED

Series + Treatment		*No. of plants*	*Weight in gm.*	*Mean weight per 100 plants*
1 Control	Shoots	79	10.561	13.36
	Roots		5.15	6.54
	Total		15.71	19.90
2 plus C 5	Shoots	38	49.02	129.00
	Roots		16.25	42.76
	Total		65.27	171.76
3 plus C 5 salts	Shoots	61	30.70	50.32
	Roots		12.35	20.24
	Total		43.05	70.56
4 plus C 1	Shoots	75	63.05	84.06
	Roots		22.27	29.69
	Total		85.32	113.75
5 plus C 1 salts	Shoots	79	17.85	22.59
	Roots		7.87	9.96
	Total		25.72	32.55
6 plus CM.	Shoots	73	69.02	94.54
	Roots		25.37	34.75
	Total		94.39	129.29
7 plus C 5 Extract	Shoots	40	8.65	21.62
	Roots		4.17	10.42
	Total		12.82	32.04
8 plus C 1 Extract	Shoots	40	5.68	14.20
	Roots		2.40	6.00
	Total		8.08	20.20

GROUP II. DRAINAGE NOT RETURNED

1Control	Shoots	56	11.95	21.34
	Roots		4.58	8.18
	Total		16.53	29.52
2 plus C 5	Shoots	43	52.07	121.09
	Roots		15.30	35.58
	Total		67.37	156.67
3 plus C 5 salts	Shoots	53	35.97	67.87
	Roots		13.05	24.62
	Total		49.02	92.49
4 plus C 1	Shoots	52	43.40	83.46
	Roots		12.83	24.67
	Total		56.23	108.13
5 plus C 1 salts	Shoots	74	22.98	31.05
	Roots		9.76	13.19
	Total		32.74	44.24
6 plus CM.	Shoots	64	59.42	92.84
	Roots		21.50	33.59
	Total		80.92	126.43
7 plus C 5 Extract	Shoots	33	10.77	32.63
	Roots		4.20	12.72
	Total		14.97	45.35
8 plus C 1 Extract	Shoots	34	9.87	29.03
	Roots		3.67	10.79
	Total		13.54	39.82

Reference No. 6, Chapter IV
ENDOTROPHIC MYCORRHIZA

(Extract from paper by E. J. Butler of the Agricultural Research Council published in the *Transactions of the British Mycological Society,* Vol. 22, Parts 3 and 4, 16th February 1939.)

'. . . the roots of most flowering plants and ferns, and the prothalli of the liverworts amongst the Bryophyta and of some of the Pteridophyta are subject to invasion by fungi belonging, with few exceptions, to a homogeneous type characterized by the possession of special organs, the vesicles and sporangioles. These fungi are not found in all roots and appear to be rare in many plants in particular localities. The evidence from cotton and the cereals shows, however, that absence or rarity of the fungus in one place is not inconsistent with prevalence in the same plant elsewhere. The association is, to a certain extent, casual, as has also been pointed out by Miss Ridler (1923) in Lunularia, but it need not on that account be without significance to either or both the partners in the association. Indeed the elaborate mechanism for the manufacture of fatty substances and their rendering to the higher plant can scarcely have no significance. With this mechanism must be associated the peculiarities of the special organs of the endophytes in question. The vesicles are constructed so as to store considerable volumes of an oily substance free to be reabsorbed back into the mycelium without the intervention of a septum to block the passage, and these stores of oil or fat are emptied into the root cells from the sporangioles. The latter are so designed as to offer the maximum of surface to the disintegrating action of the cell juices. They are not merely artifacts due to a 'digestive' action of the cell on the fine branches of the arbuscules as appears to be suggested by some observers, but are definite bladders formed at the tips of these branches and passing through a stage or turgidity before they break down. Nor are they haustoria engaged in absorbing nutriment from the host cells as has also been suggested, for their formation often marks the end of the vegetative activity of the fungus in a particular region, or in a considerable area of fine roots simultaneously. That they have some function in the developmental nutrition of the higher plant, as most students of them have suggested, can hardly be doubted. The purely tentative hypothesis is advanced that this is not the supply of fat as such but of some fat-soluble growth or development promoting accessory substance. The extraction of sufficient quantities of this hypothetical substance would present great difficulties so long as the endophyte defies artificial cultivation; but in certain plants such as bamboos or *Ricinus communis,* the volume of the endophyte may be very considerable in the white roots and it might be possible to obtain appreciable quantities of the fungus. from them at an appropriate season.'

Reference No. 7, Chapter VI
A
PREDACIOUS FUNGI
(Dr. C. Drechsler, *Biological Reviews,* Vol. XVI, 1941)

'When Rouband and Descazeaux (1939) added larvae of strongyloid nematodes parasitic on the horse, belonging to the genera *Strongylus* and *Tribonema,* to agar cultures of *Arthrobotrys oligospora* and *Dactylella bembicodes,* the very active strongyloid specimens were captured and consumed in quantity. *D. ellipsospora* showed similar though lesser predacious capabilities in relation to these parasites. However, the very sluggish rhabditiform larvae apparently evoked very little development of predacious apparatus.

'Descazeaux (1939a), in determining that strongyloid larvae of the genera *Strongylus* and *Tribonema* were captured by *Arthrobotrys oligospora* and *Dactylella bembicodes,* made use of nematodes newly hatched from a pasty mixture of dung and powdered charcoal. The mixture was kept confined in crystallizing dishes covered with inverted bases of Petri-dish cultures of the two fungi. Several strips of moist paper placed vertically in the containers provided passageways suitable for migration of newly hatched animals from the dung paste to the agar cultures. Predacious organs, the formation of which began 24-36 hours after the relatively early arrival of rhabditiform larvae, operated especially effectively against the tardier strongyloid larvae, with the result that in 20 days all the larvae that emerged from the dung were exterminated. In a later paper Descazeaux (1939b) reported that larvae of the family Trichostrongylidae, which are parasitic in the digestive tracts of cattle and sheep, were captured and killed in predacious apparatus formed after their addition to cultures of *Arthrobotrys oligospora* and *Dactylella bembicodes.* Likewise, when conidia of either fungus were added to water containing such larvae, predacious organs were formed by means of which the animals were captured and killed.'

B

'Deschiens and his colleagues admit that possibly even under ordinary natural conditions the predacious hyphomycetes in some measure carry on destruction of infectious nematode larvae. By providing for increased mycelial development through application of fungus material--the increased development reported by them seems greatly in excess of expectations--they aim to augment the activity of the predacious hyphomycetes to the point where it becomes effective as an important subsidiary, if not principal, prophylactic factor. Manifestly their treatment by extensive application of fungus material departs markedly in principle from the treatment investigated in Hawaii, whereby large quantities of organic matter are incorporated in the soil. The former treatment would seem to be based on the idea that nematode-capturing fungi are meagrely distributed in nature, and yet are addicted to very aggressive saprophytic development when brought into contact with foul natural substrata; whereas the latter treatment postulates rather that the fungi in question are very generally distributed in soil and decaying materials, that they subsist habitually on nematodes, and that. accordingly they can best be stimulated in vegetative development and useful predacious activity by first supplying them with larger quantities of saprophilous living prey.'

Reference No. 8, Chapters V and VI
THE EARTHWORM

F. H. Billington, in his book *Compost,* mentions how as a result of the interest aroused by the three volume book *Our Friend the Earthworm* by Dr. G. S. Oliver of

Texas, and the latter's enterprise in breeding earthworms to supply to farmers, and for other purposes, 'much barren land from which the earthworm had been banished by chemical manures and poison sprays, has been restored to fertility'. He gives the American *Nature Magazine* of January 1941 as his authority for this statement.

He then supplies the following facts which make such claims understandable:

'(1) Darwin found that in an average English soil, earthworms brought to the surface about ten tons of castings per acre per annum. These are now known to consist of neutral colloidal humus, the only form immediately available to plants. It is safe to assume that in a warmer climate, or with improved types of worms such as the 'Coolie', this figure might be much larger.

'(2) The estimated numbers of earthworms per acre in the soils of the Rothamsted Experimental Station, England, are stated to be, very roughly: (a) 0.5 million on unmanured land; (b) 2.75 millions on farmyard manured land; (c) 8.6 millions on grassland.

'(3) Earthworms render soil permeable to rain thus checking the tendency to erosion by rain and wind. Aeration and nitrification are also stimulated.

'(4) They mix organic matter thoroughly throughout the soil and prevent its undue accumulation in peat-like layers on the surface, e.g. old, matted, sour pastures.

'(5) Earthworms are excellent subsoilers; what they bring up of this soil is vastly different to the crude material resulting from subsoil tillage. Soil and organic matter swallowed by the worms are thoroughly pulverized in their fowl-like gizzards, and mixed with digestive secretions.

'(6) Earthworms perform equally useful work in the compost heapabundance of them is a sure sign that the process is going well, just as their eventual withdrawal, in a normal way, is an indication that the compost is ready for use.

'Earthworms are very sensitive to acidity or purely chemical salts, whereas such materials as the wastes of the onion family and natural sugary materials, encourage them.'

Reference No. 9, Chapter VIII
CELLULOSE DECOMPOSITION TEST AT HAUGHLEY

The soils to be tested were removed from the fields concerned in sections 18 inches deep and transferred to large boxes so that the original layering remained intact. These boxes were then sunk in the ground so that the level of the soil inside and out was the same. After treatment the boxes were planted with cabbages to reproduce field conditions.

Source of Soil and previous treatment	Treatment on 11th July 1946	Ph. Value at completion of experiment
1. Arable field B1 (in-organic fertilizer since 1940)	21b. chemically activated compost, 1/2 oz. superphosphate, 1/8 oz. potassium sulphate, 1/8 oz. ammonium sulphate	7.65
2. Arable field Ca 1946 meat and bone, 1945, 1944, inorganic, 1943 F.Y. M. and compost	2 lb. farmyard manure, fertilizers as in Box 1	7.8
3. Virgin soil under grass and natural herbage. No treat-ment since 1920	2 lb. standard compost (FYM and mixed straw)	8.8
4. Ditto	Nil	7.88
5.Ditto	3/4 oz. superphosphate, 1/4 oz. potassium sulphate, 1/4 oz. ammonium sulphate	7.63
6. Same as No. 1	3/4 oz. superphosphate, 1/4 oz. potassium sulphate, 1/4 oz. ammonium sulphate	8.0
7. Arable field A6. Compost or FYM since 1940	21b. standard compost	7.73

Note: 25 oz. per box = 10 ton per acre.
1/4 oz. per box = 2 cwt. per acre.

The experiment was brought to an end in January, 1947. The results were as follows:

Box No.	Weight of cellu-lose cone as in-serted in July 1946 gms.	Weight of cellu-lose cone as re-covered in Jan. 1947 gms.	Difference: be-ing actual weight of cellulose de-composed gms.	Percentage of original cone decomposed per cent
1	1.39	.96	.43	30.9
2	1.39	.63	.76	54.7
3	1.39	.04*	1.35*	97.1*
4	1.39	.23	1.16	83.5
5	1.39	.72	.67	48.2
6	1.39	.88	.51	36.7
7	1.39	.74	.65	46.8

* The fibres recovered from box 3 proved on closer examination to be rot fibres and not cellulose fibres. Percentage of decomposition therefore in this box is presumed to be 100.

Observations

Arable Soil (Boxes l, 2, 6 and 7)

The following points are worth noting:

(*a*) The contrast between these boxes is nothing like so striking as that between the three boxes of virgin soil, indicating the reduction it soil fungi and bacteria that results from continually turning the top soil and exposing it to sun and air.

(*b*) Such differences as do occur suggest that soil treated with anima residues or by-products possesses greater biological activity than soi where no such treatment has been given. The greatest decomposition, it will be noted, took place in boxes 2 and 7, the first of which received FYM plus meat and bone meal in addition to the NPK, and the second of which was treated with compost only.

(*c*) The FYM plus meat and bone meal in box 2 appears to have counteracted the depressing effect of the inorganic fertilizer, an effect which is very apparent in boxes 1 and 6 where inorganics are not accompanied by any animal manure or by-product.

(*d*) It is particularly noteworthy that the least decomposition of all took place, not in the soil treated with pure inorganics but in that containing a mixture of inorganics and chemically activated straw compost. Tentative deductions are that inorganic NPK has a depressing effect upon the cellulose-decomposing organisms; that FYM and meat and bone meal mitigate this effect; but that the addition of straw compost, when activated by inorganic nitrogen, increases it.

Virgin Soil (Boxes 3, 4 and 5)

The result here is very much more striking. The contrast between 2 (compost treated) and 4 (chemically treated) being over 50 per cent, with the untreated box about halfway between.

The 83½ per cent decomposition in the untreated box clearly indicates that a larger number of organisms were initially present. That a single application of compost should have so greatly increased their activities, and a single application of NPK so greatly reduced them, is of considerable interest. That the result in box 3 was not due simply to the introduction of the additional organisms present in the compost is shown by comparing box 3 with box 7, each of which received the same amount of compost.

(NOTE: The greatly increased population of soil bacteria present in ground which had not been upturned or uncovered for many years would seem to be a pointer towards explaining the success which some cultivators are having with the new no-digging technique; also long leys as restorers of fertility.)

Reference No. 10, Chapter IX
SERVICE AGRICULTURE

The following reasons for establishing a 'service agriculture' round our main centres of population are taken from Broadsheets issued by the Association for Planning and Regional Reconstruction, 32 Gordon Square, London, W.C.l. This excellent and enterprising organization has worked out the technical details, with full tables of figures, of how such a scheme might be organized. Readers interested in this aspect of post-war planning should apply for Broadsheets Nos. 4, 5, 6 and 7.

'A town or city's fresh food supply might be its first and most important health service. Instead, it receives less attention than water, gas, electricity and sewerage, and is regarded as a legitimate field for cutthroat commercial competition. Without a constant supply of the vital fresh foodstuffs, bodily and mental health cannot be maintained.

The Case for a Service Agriculture

'There are good reasons why the vital fresh foods should be produced close at hand:

'(1) Appearance, taste, food value, vitamin value, and water content are all retained at their best.

'(2) Losses in transit (especially in hot weather), delays in transit (especially in cold weather), and handling losses, are all reduced.

'(3) Transport problems and transport costs can be substantially reduced by good planning, including the return of empty bulk containers to the farm without their ever having left the district.

'(4) Waste organic matter can be returned to the land, either as scraps, swill or compost; a local surplus of any product can be processed or otherwise used locally.

'(5) A healthy mixed farming tradition close to and surrounding the centres of population means healthy land and healthy people; the green leaf area of the district is increased and its period of activity lengthened; the humus content of the soil and therefore the water content of the area is maintained.

'(6) The possibility of closer co-operation between town and country arises, and in particular every child-as part of its education-is able to see the essential processes that produce its essential food; the need for formal 'parks' is less, so long as reasonable access to the land is allowed to the ordinary citizen and his family.

'(7) The quality of a vital fresh food depends on the primary producer; under present conditions the processor and the distributor only delay the rate at which deterioration takes place--they cannot improve quality; advisory control during production of its vital foodstuffs therefore becomes a proper course for a community to follow, instead of existing haphazard recriminatory control--by inspectors--of process and distribution.

'(8) The fresh foods available to a community should be the best that that community and its immediate surroundings can produce; there is no place in a healthy community for vital foodstuffs of varying quality or doubtful origin, nor for cut-throat advertisement and self-whitewashing by rival retailers who themselves frequently have had no hand in production.

'(9) Every place where fresh food is produced or handled should be accessible and available for inspection by any responsible citizen at any time, and designed accordingly.'

Reference No. 11, Chapter IX
UTILIZATION OF WASTES

Members of Town, Borough, and Urban District Councils, as well as Local Government Electors are referred to the paper 'Sludge and Refuse as National Assets in War and Peace' by C. C. J. Bullough, a practical Sanitary Engineer, and Associate of the Institute of Sewage Purification. (Registered Office: 34 Cardinal's Walk, Hampton-on-Thames, Middlesex. Hon. Sec. W. F. Freeborn.)

This paper was prepared for the special attention of the Institute's newly formed Post-War Reconstruction Committee. Mr. Bullough goes very fully into the details of the technique and costs of composting town wastes and sewage sludge. He presents his subject in a highly readable form. The following is a summary, with quotations, of some of the most important points in his paper.

'As is well known, means have already been found in certain works for the utilization of the purified effluents: the author's present subject, however, is confined to the sludge and screenings. In view of their important physical and, to a lesser extent, of their chemical properties; and in view also of the fact that they so often cause so much worry and anxiety in the operation of sewage works, it is most unfortunate that in the past so little has been done to realize the latent value of these materials and thus relieve sewage works operation of an incubus.

'This present Paper arises from the author's desire to bring to the attention of the Post-War Reconstruction Committee the practicability of dispensing with sludge handling, treatment and disposal processes, together with screenings disposal, by using the materials in their wet state for the production, by natural fermentation, of organic manure. That changes the aspect "sludge disposal" into the aspect "sludge utilization" and, as the use of house refuse is involved simultaneously, the same transformation occurs in the aspect from which house refuse may be regarded. "Sludge" is taken to include screenings, and "refuse" to include all trade and other wastes of an organic nature.

'All these substances have commonly been thrown away or deliberately destroyed and it would seem that, since their simultaneous utilization in a favourable way can be accomplished, with the additional virtue that components of the house refuse useful as raw materials of industry are at the same time extracted in an efficient manner, this whole subject appears particularly appropriate for consideration by the new Committee.'

Mr. Bullough points out that three of the important problems of the post-war period will be: (*a*) maintenance of soil fertility; (*b*) world shortage of ocean tonnage; (*c*) the necessity for a greater measure of economic self-support. This last question is very largely bound up with the 'prevention of waste'.

'It is not very difficult to recognize that the conditions outlined in (*a*), (*b*) and (*c*) above exist also during the course of the war, and to an intensive degree. Whilst it is obvious that they must be met after the war if the peace is to be won, an even more fundamental consideration is that they must be met during the war if the war is to be won; failing which the organization of the peace will be in hands other than those of the members of this Institution!'

Answering the criticism that expenditure by municipalities on disposal plants could not be justified in war-time he states:

'When it is considered how little money and materials need be expended on the construction and operation of salvage plant, compared with the continuous flow of vitally required products from such plant; and when it is realized that such procedure affords immediate relief to a number of associated and equally vital functions of the national war effort, the situation can be seen in a great deal better proportion. In the way of example, it may be pointed out that the amount of steel alone that can be recovered from a properly designed and efficiently operated plant in a year's working amounts to several times the weight of steel employed in the construction of the plant. This is just one out of many possible illustrations of the necessity for judging carefully, and of the certainty of judging favourably, the question as to whether expenditure of money and materials in this highly productive manner is not one of the foremost duties of war-time policy as well as of any scheme of postwar reconstruction.'

He divides the operating process of such plants into five phases '(1) removal of "salvage" from the refuse; (2) screening of the residue so as to remove two grades of "ash"; (3) pulverization of the material remaining; (4) addition of sludge to the pulverized refuse by a process of "composting"; (5) storage of the compost for a "maturing" period. . . .

'Works have been operating on these lines for years at Leatherhead and Maidenhead and have been described elsewhere. Both these plants suffer from having been installed before the possibilities and adaptability of the process had been substantially developed; but their continued satisfactory performance is the more creditable for that reason.'

Despite the adverse conditions 'the entire annual cost to the Borough Council for "disposal" of Maidenhead refuse and sludge simultaneously is substantially less than the average cost of disposal of *refuse alone* among the whole of the non-county boroughs of the country, as given in the Ministry of Health returns. The plant is operated under contract by the proprietors of the process. . . .

'The "wastes" in question can be completely and successfully converted into saleable and much-needed products, by the methods here proposed, without the assistance of machinery of any kind. It follows therefore that, provided the essential principles of the process are known and implemented, the products will be entirely satisfactory. The choice of plant and layout is governed by the familiar considerations as to how far and by what means the various operations can be controlled and mechanized in order to secure the greatest efficiency, reliability and economy obtainable in local circumstances. The knowledge and experience now available enable these factors to be readily determined.. . .

'Certain articles are removed from the refuse because (1) they are needed in industry, (2) their sale provides a source of income, (3) some are either useless or detrimental in the manure.'

A detailed description of the screening operation then follows. The material which fails to pass through the screen has been found to be 99 per cent saleable as salvage. The screened matter is then crushed in order: '(1) to render it more homogeneous before composting; (2) to dissipate any remaining few lumps, e.g. of clinker, wood, etc., that may have baffled the pickers or the screen and (3) to achieve the all-important purpose of enormously increasing the free surface area of unit quantity of material. Since composting and maturing consist of a series of 'attacks' on the material by various agencies, they will be facilitated as the area of accessible surface. . . .

'Composting enables the two remaining materials--crushed refuse and sewage sludge--to be utilized in the production of manure. It enables the refuse-tip and the incinerator to be closed down for good. It obviates the further use of open and covered sludge drying beds, lagoons, filter-presses, chemicals, vacuum filters, etc. It involves no permanently increasing immobilization of space. By means of composting, refuse is no longer a generator of fire, smoke and vermin; sludge is no longer a cause of smell, sourness and depreciation of site-values. Composting enables all expenditure in connection with these factors to be avoided or put an end to. The cost of composting is recoverable by sale of the manure produced.'

A detailed technical description of the composting process then follows, ending with the following data for a 50,000 population. The figures given for expenditure and revenue are all based on actual operating experience.

'Refuse 40-50 tons per day. Plant designed to deal with input of 9 tons per hour leaving 3½ hours per 8½ hour day free for the men to carry out baling, sorting, packing operations, etc., to shift compost, maintain the plant and so forth. Many of such operations do not occupy one man's time and this principle avoids "specialists" wasting most of their time, whilst providing for increase of population without further plant. Receiving hopper 100 cu. yds. flush capacity, with heaping and side space of a further 50-60 cu. yds. Six composting bays 14" wide 40' long. Belt conveyor under receiving hopper, 30" wide 70' centres 25' per min. 9 tons per hour 5 h.p. motor. Inclined conveyor passing through bottle picking shed and feeding screen: 30" wide 100' centres 40' per min. 9 tons per hour 5 h.p. motor. Rotary screen 6' dia. 18' long 5/16" and 1½" mesh, 15 h.p. motor. Magnetic belt conveyor 30" wide 5" centres 25' per min. driven from picking belt conveyor. Garbage separator: 48" wide 10' centres

10' per min. driven from screen drive. Picking belt conveyor 30" wide 32' centres 25' per min. 9 tons per hour driven from crusher drive. Crusher 5 tons per hour 80 h.p. motor. Crushed refuse conveyor 12" wide, 97' centres, 200' per min. 5 tons per hour 5 h.p. motor. Travelling scraper conveyor for distributing crushed refuse in composting bays; 12" wide, 35' centres, 90' per min., 5 tons per hour, 5 h.p. motor. Portable stacking conveyor for shifting compost: 20" wide 50' centres, 200' per min., 3½ h.p. motor or engine. Approximate cost excluding civil engineering work and ash hoppers £5,500. Approximate cost of civil work £5,000. Estimated annual consumption of electricity 72,000 units, say £225. Motors for this class of work must of course be of considerably greater horse-power capacity than that of their actual average load. Sludge 36 tons per day 95 per cent water content. Income from salvage £5,000 per annum. Income from ash £900 per annum. Production of manure 6,000 tons say £2,700 per annum. Cost for labour £2,400 per annum. Arable acreage required to absorb entire output of compost, at 20 tons per acre: 300 acres annually. Area swept by haulage radius of 4 miles: 32,000 acres, 10 miles: 200,000 acres.'

The following facts about the different materials composing municipal wastes are of interest.

'*Refuse.* One of the Universal Variables. Town refuse is an unprepossessing mixture that has nevertheless a heart of gold. Unless very fresh it develops a disgusting odour and it is notorious for its dust. In spite of this it shares with sewage the remarkable reputation that those who work regularly with them maintain exceptionally good health, even in an epidemic, and are, in particular, notably free from ailments so easily attributed to them. Refuse varies with locality and season in a complex way. From the point of view of composting, town refuse may with advantage be supplemented by slaughter-house waste, grass cuttings, gardening refuse, fish offal, market sweepings and certain factory wastes such as pressed fruit pulp, vegetable cleanings, and almost anything else of a vegetable or animal nature.

'*Sludge.* All forms of sewage sludge make successful compost. Screenings are included in the category for this purpose. Digested sludge is perhaps a trifle slower in action due possibly to its initially anaerobic nature but should be free from pathogenes. Activated sludge surplus to plant requirements, in spite of its exceptionally high-water content, composts very well indeed. The high nitrogen content of its solid matter is valuable. The settlement and filtration properties of activated sludge, which have caused so many difficulties, have no adverse effect on composting except in so far as they involve the sludge reaching the plant at a very poor degree of concentration. A little study of the many and violent differences between a compost bed and thin, close, cold, lifeless long-term continuous-flow media such as filters or drying beds will reveal many reasons for its superior performance.

'*Salvage.* It can now be said that a useful purpose exists for every component of refuse that is not wanted in the manure. This may sound an ambitious statement when the mind turns to broken wash-basins, fragments of wood, discarded boots and the like; but recent work in the author's knowledge establishes the fact so far as all components known to him are concerned. It is unlikely that nothing whatever will be thrown away on small plants and indeed there is a total in the Maidenhead records, amounting to under 1 per cent, of such "reject" material; but means have been fully worked out for very large plants to enable every single piece of refuse to be turned to profitable purpose-some indeed on the works itself. The chief classes of salvage regularly recorded at Maidenhead are tins, iron, non-ferrous metals, dry batteries, lead, syphon tops, bottles, jars, milk bottles, cullet, paper, cardboard, rags, bagging, carpet, gunny, horsehair, skins, bones, feathers, tyres and rubber. Nearly all these are in practice considerably subclassified and they by no means complete the list. It may perhaps be said without risk of contradiction that the diversity of articles obtainable from refuse is equalled only by that of the things which are put into it!

'Ashes. The larger grade of ash is a very valuable fuel, and can be used with success for heating buildings, glasshouses, brick-kilns, etc. "Cinders" recovered from Halifax refuse are stated to have calorific value of 810,000 B.T.U.s per lb. and to be used for raising steam at the sewage works. The fine dust is of great value in agriculture. It contains the 'dust of the household, including the produce of vacuum cleaners, which contains much wool and other textile fibres. Maidenhead ash, screened through 5/16" mesh, has given astounding results, e.g. on extensive lawns as a top dressing. When the user learned that labour was no longer available at the works for screening he arranged for more material to be delivered in its raw state and had the screening carried out locally!

'Remarkable work has been done on the agricultural applications of this material, notably at the Hannah Research Institute by Dr. A. Fowler, Dr. S. Morris and Mr. W. B. Strain. Fine ash at Ayr contained all the known important "trace" elements and spectrographic analysis of the Maidenhead material confirms this finding. Organic matter in this ash is from 20 per cent to 30 per cent of the dry matter through 5/16" mesh. Whilst the ash is largely composed of coal residues it should be remembered that coal is a vegetable residue. It is not surprising that fine ash provides so many of the factors necessary for successful plant-culture.

'This "dust" is already in use in large quantities in the more enlightened agricultural districts and the Ministry of Health lists some seventy sources in England and Scotland where screening is employed at 5/16" to ½" gauge.

'Crushed Refuse. Pulverization effects remarkable changes in refuse. Flies, which infest the raw material, are almost entirely absent beyond the crusher. The objectionable smell disappears and a much fainter, less unpleasant aroma may be detected. Mention must be made of the pioneer and almost classic work that has been done at Southwark on the crushing of refuse for manure. This material has also been extensively used for covering old refuse tips, without nuisance of any kind and at some useful saving in cost. The author was giving evidence before a committee of the House of Commons with the Borough Engineer of Southwark when Mr. Smart brought out of his pocket a jar of the same day's crushed refuse to illustrate a point. This was passed round and earnestly smelt by a number of M.P.s and others to their evident pleasure and amazement.

'Compost. The wholesome fermentation of the crushed refuse and sludge is probably responsible for its lack of attraction for flies and vermin. Occasionally rat-holes are noticed in the maturing heaps when the weather is very bitterly cold. It is evident that they seek warmth, for no sign is found of any attempt to consume the material. As the material breaks down more completely it becomes progressively

cooler and takes on more and more the appearance of leaf-mould. Only the extreme outside skin shows any significant detail of its origin. All odour has vanished save a faint earthiness. Weed seeds and pathogenes have succumbed and not a green leaf appears on the piles except for an occasional "annual" carried by the wind on to the extreme surface of the pile, where the sun usually withers it promptly. The absence of tomato seedlings will be of special interest to Sewage Works Engineers.

'Agriculturists kick the stuff with relish, as they do a newly turned clod. Laymen, scientists, councillors, borough engineers, poke about in it delightedly with a walking stick or even a very good umbrella. The fact of the matter is that there is nothing about the process to be seen, that is impressive, except the manure. The manure is certainly impressive. The rest is a matter of engineering technique and of economics--old bedfellows.

'Those, then, are the chief materials involved in sludge and refuse utilization. What are the advantages to the public, as residents and ratepayers, of undertaking such methods, apart from pure moral beauty --a quality sometimes regarded as insufficient in those quarters?

'Perhaps the first practical advantage is that capital and operating costs for sludge are swept right away altogether. The same applies to costs of refuse-disposal. These solid savings of money and worry bring about at once a great improvement in amenity. Site and rateable values improve in consequence and no more space is written off the development programme every year. Relatively unskilled labour can be used, without highly trained scientific administration. Costs and incomes associated with the process are such that sludge and refuse can be lost sight of at a lower charge on the rates than the normal cost of refuse disposal alone. That sensitive place having been touched, it is perhaps permissible to recall the moral or logical position. There can, in the circumstances outlined, be few ratepayers who will not endorse the total prevention of waste and the fortification of the soil.'

In addition to Maidenhead and Leatherhead, the following places have undertaken the utilization of municipal wastes:

Manchester. Pulverized humus from controlled tips.

Southwark. Crushed town refuse.

Kensington. Bacteriological conversion of town waste by Hyganic Ltd.

Ficksburg, South Africa. Composting night soil, slaughter-house refuse and town rubbish. (Most other towns in South Africa have now followed suit.)

Nairobi, Kenya Colony. Composting coffee parchment, boma manure, tannery waste, hair, wool and fleshings, horn and hoof, bones, cotton seed residues, chaff, wood ashes, and crude limestone.

Many towns in India. Composting night soil and town rubbish.

In all these and other cases, the process has been entirely successful both from a sanitary point of view, and in the ready demand which exists for the resulting compost as manure. Messrs. Arthur Guinness, Son and Co. Ltd. use 10,000 tons of the Southwark product annually in their hop gardens, where they compost it with ordinary farm wastes.

Reference No. 12, Chapter IX

A SANITATION PROBLEM AND ITS SOLUTION

Under the above title, Dr. Aubrey Westlake (A. T. Westlake, B.A., M.B., B.Chir., M.R.C.S., L.R.C.P.) has written an interesting account of the system of sanitation he has adopted at the holiday centre and camping ground which he started in 1938 on his estate in Hampshire.(Published in *Compost News Letter No. 4*.) As many as two thousand people passed through this centre in pre-war days in a single season, and even under war-time conditions, Dr. Westlake has a resident population of forty to fifty, so sanitation was quite a problem.

At first he adopted the Dr. Poor method of placing the night soil in shallow trenches, covering with earth and leaving to decompose. Special' earth closets were provided at convenient places in the camping ground, and in all of them, whether for men or women, separate urinals were provided. 'The advantages of this separation,' he writes, 'are three: (1) and very important aesthetically, the closet keeps sweet and remarkably free from smells usually associated with such structures, certainly much more so than any chemical closet I know. The dried earth acts as the finest deodorant I know. (2) The collection and emptying is made very easy and unobjectionable, and (3) the decomposition of the faecal material commences immediately in the dry earth buckets.'

Everyone told him that it would be impossible, in the case of women, to achieve this separation, but he found it quite practicable. 'Considering that I deal with a clientele brought up exclusively on W.C.'s I have been amazed with the way in which, on the whole, the arrangements have worked satisfactorily.'

In the autumn of 1938 Dr. Westlake met Sir Albert Howard and decided henceforth to compost the night soil with other camp refuse by the Indore process; this system has been continued ever since. His method of collection and disposal is by motor truck with a trailer tank. The night soil is emptied into the truck, and the urine into the tank. The kitchen wastes and other refuse of the camp are collected at the same time. It is then all taken to the garden, and there composted, by the Indore process, with the garden rubbish. Wood ash, which happens to be available, is mixed with the compost as well as soil and hydrated lime. The urine is used for moistening the heaps. The compost is turned in the usual way and when mature is used on the garden. Dr. Westlake records that 'The results of its use cannot be in doubt. From growing practically nothing the garden is now most fertile and grows excellent crops.'

He concludes his account as follows: 'I feel that this has been a most successful and useful experiment. It has solved in a very simple, practical and efficient way, and

I might add, a cheap way, what might have been an extremely difficult sanitation problem. . . .

'It has demonstrated quite clearly that it is perfectly practical to deal with night soil on the scale I have had to deal with it and there has been no shadow of any sort of nuisance. Indeed, the heaps, either when being built or when completed are completely inoffensive and have not even flies or any other nuisance infesting them. (In very hot weather for an hour or two after pouring on the urine, there may be some smell.) It is a complete vindication of the composting method as advocated by Sir Albert Howard and shows quite clearly that such a scheme could be used by any small village, and certainly by any camping ground or similar institution in the country. Above all it is a constant source of satisfaction that one is doing one's small share in increasing the fertility of our countryside, important now in war-time and infinitely more in the days to come, and in restoring the complete natural biological cycle from man to earth and back again, so adding to the actual and potential health of all who come within the range of this experiment.'

An easier method than that adopted by Dr. Westlake of effecting a separation of faecal matter and urine in earth closets was invented by Dr. L. H. Picton. It is described and illustrated in his 1919 annual report to the Winsford Urban District Council (of which he was for many years M.O.H.) who have given me permission to reproduce this description and drawing. (See Fig. 9.)

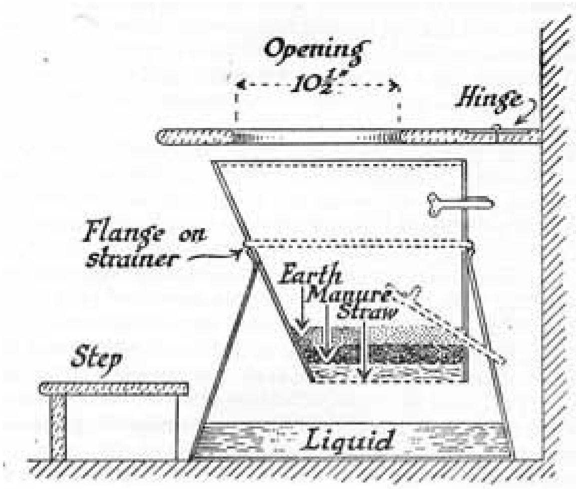

FIGURE 9

'A galvanized iron bucket with a wide base. A strainer fits into the bucket; straw, etc., is put in the strainer. Black dry garden soil is thrown upon the solid manurial matter that falls on the straw. The urine runs through the strainer. This closet if emptied every day or two is odourless, and the surface of the strainer's contents is a layer of dry earth, through which the smell of the urine in the bucket below does not pass.'

Even when applied to the soil direct and not composted, Dr. Picton states that 'about one-quarter of a rod of garden will suffice to receive perpetually the nightsoil of a cottage scavenged on this principle. The nitrifying organisms in the soil completely and rapidly convert the manure to soil; in about three months the conversion is quite complete. Provided the top layers, which alone contain the nitrifying organisms, are used the soil retains all, and disinfects all, the bacterial contents of the manure, and the subsoil water receives no contamination.'

Reference No. 13, Chapter IX
NIGHT SOIL AND SEWAGE AS MANURE
(Bio-Dynamic View)

The view referred to, is based on the theory that, in so far as the life cycle is concerned, man must be considered as differing biologically from animals. It follows therefore that human wastes cannot be regarded as an interchangable alternative to animal wastes. Thus any compost used for growing crops for direct human consumption must include the wastes of both plants and animals. Compost containing vegetable and human wastes only should be used on crops for animal consumption, for if the sequence is: man, soil, plant, and back again to man direct, the omission of the animal element causes just as serious a break in the nutrition cycle as omission of the fungus, or the plant. A break anywhere in this cycle is equal undesirable for health, since health is wholeness.

The animal's nutrition cycle is not broken by omission of human wastes, partly because plants and animals preceded man in evolution, and therefore the cycle without man is complete in itself. This cycle was merely enlarged to include man, his arrival does not mean that any part of the original cycle can be short-circuited with safety.

Reference No. 14, Chapters V and VI
Extract from paper by Dr. Chalmers Watson (retd), September 1943.
A 'VITAL' V. 'CHEMICAL' FACTOR

'The existence of a "vital" function and "vital" property in foods was strikingly suggested to me forty years ago from the extensive series of investigation on nutrition, which extended over many years, in which many qualified researchers took an active part, the term "vital" being defined as "instinct with life". . . . Some years later this subject was brilliantly illuminated by the discovery of "vitamins" by Hopkins and others. Immensely valuable as "vitamins" are in the treatment of sick men and sick animals, a lengthy medical experience has convinced me of the pre-eminent importance of securing these vitamins as far as possible from fresh foods grown in a healthy soil.

'Great caution is necessary in accepting too readily the conclusions arrived at from highly skilled laboratory research work as being applicable to the established practical conditions which called for the research. This is emphasized by the following experience. Many years ago the curative influence of sunshine on rickets was fully established, as was also the special value of milk which had been irradiated by the "ultra-violet rays", Vitamin D being essentially the responsible factor in the cure. Curiosity then prompted the examination of a sample of irradiated milk by highly skilled laboratory test to determine the presence and relative amount of

Vitamin D. The official report revealed the presence of Vitamin D, but "in very small amount compared with that present in certain medicinal preparations of Vitamin D". Neither the skilled finding of the laboratory test nor the *bona fides* of production of the remedy were for a moment questioned. What did appear to me, however, to be open to question was the too great readiness to apply conclusions from laboratory findings alone or too largely, in the absence of the experience and opinion of the skilled practical men in the industry who had an intimate knowledge of the practical side of the problem which formed the basis of the research. To illustrate--I had just then seen a few cases of advanced rickets which had been treated for some months under careful hospital conditions, the treatment including the medicinal vitamins referred to in the Report, in which, when the milk which had been used for some months in the diet without any apparent benefit, was replaced by an equal amount of milk which had been appropriately irradiated with ultra-violet rays, a very remarkable recovery indeed took place in a few weeks, all the other conditions of treatment having been maintained throughout. Taking the long view, I am satisfied that "science" as sometimes now applied may become a grave national danger. . . .'

BIBLIOGRAPHY GENERAL

ALEXANDER, A. J. P. B., *God Speed the Plough* (The Richards Press Ltd., 1940).

BAKER, A., *The Labouring Earth* (Heath Cranton, 1940).

BARLOW, DR. E. K., *The Discipline of Peace* (Faber and Faber, 1942).

BARRETT, T. J., *Harnessing the Earthworm* (Faber and Faber, 1949).

BILLINGTON, F. H., *Compost* (Faber and Faber, 1942).

BRUCE, MAYE E., *From Vegetable Waste to Fertile Soil* (Faber and Faber, 1943).

----------, *Common-Sense Compost Making* (Faber and Faber, 1945).

CARREL, DR. A., *Man the Unknown* (Hamilton, 1935).

CHRISTOPHERSEN, ERLING, *Tristan da Cunha* (Cassell, 1940).

DARWIN, CHARLES, *Darwin on Humus and the Earthworm: The Formation of Vegetable Mould through the Action of Worms,* with an introduction by SIR ALBERT HOWARD (Faber and Faber, 1945).

ELTON, LORD, *St. George or the Dragon* (Collins, 1942).

FORDHAM, M., *The Land and Life* (Routledge, 1942).

GRANT, DORIS, *Feeding the Family in War-Time* (Harrap, 1943).

----------, *Our Daily Bread* (Faber & Faber, 1944).

HOWARD, SIR A., *An Agricultural Testament* (O.U.P., 1940).

----------, *Farming and Gardening for Health or Disease* (Faber and Faber, 1945).

HOPKINS, D. P., *Chemicals, Humus and the Soil* (Faber & Faber, 1945).

HUME, E. DOUGLAS, *Bèchamp or Pasteur* (Daniel, 1932).

JACKS, G. V. and WHYTE, R. O., *The Rape of the Earth* (Faber and Faber, 1939).

KING, E. H., *Farmers of Forty Centuries* (Cape, 1926).

KING, F. C., *The Compost Gardener* (Titus Wilson and Son, Ltd., 1943).

----------, *Gardening with Compost* (Faber and Faber, 1940).

LAKHOVSKY, GEORGES, *The Secret of Life* (William Heinemann (Medical Books) Ltd., 1939).

MUMFORD, L., *Faith for Living* (Secker & Warburg, 1941).

NORTHBOURNE, LORD, *Look to the Land* (Dent, 1940).

OSBORN, F., *Our Plundered Planet* (Faber and Faber, 1949).

PEARSE, DR. I. H. and CROCKER, L. H., *The Peckham Experiment: a Study of the Living Structure of Society* (Allen & Unwin, 1943).

PFEIFFER, DR. E., *Bio-Dynamic Farming and Gardening* (Steiner, 1938).

PFEIFFER, E., *The Earth's Face and Human Destiny* (Faber and Faber, 1948).

PFEIFFER and RIESE, *The Fair Garden Plot* (Steiner 1943).

PICTON, *Thoughts on Feeding.*

POLLITT, COL. G. P., *Britain Can Feed Herself* (Macmillan, 1942).

PORTSMOUTH, EARL OF, *Alternative to Death* (Faber and Faber, 1943);

----------, *Famine in England* (Witherby, 1938).

RAYNER, DR. M. C., *Mycorrhiza* (C.U.P., 1927).

----------, *Trees and Toadstools* (Faber and Faber, 1945).

RAYNER and NEILSON-JONES, *Problems in Tree Nutrition* (Faber and Faber, 1944).

SYKES, FRIEND, *Humus-and the Farmer* (Faber and Faber, 1946).

WAKSMAN, S. A., *Humus* (Baillière, Tindall & Cox, 1937). WILLIAMSON, G. SCOTT, M.D., *Physician, Heal Thyself* (Faber and Faber, 1945).

WRENCH, DR. J. T., *The Restoration of the Peasantries* (Daniel, 1940).

----------, *The Wheel of Health* (Daniel, 1938).

----------, *Reconstruction by Way of the Soil* (Faber and Faber, 1946).

PAMPHLETS

Broadsheets, Nos. 2, 3, 4, 5, 6, 7. Issued by the Association for Planning and Regional Reconstruction, 32 Gordon Square, London, W.C.1.

The Medical Testament with References (1939). Issued by the County Palatine of Chester Local Medical and Panel Committees. (Reprinted by the Soil Association.)

Sludge and Refuse as National Assets in War and Peace, C. C. J. Bullough (1942). Printedby the Institute of Sewage Purification. Hon. Sec. W. F. Freeborn, 34 Cardinal's Walk, Hampton-on-Thames, Middlesex.

Guide to a Vital Research (Soil Association, Haughley, Suffolk).

PERIODICALS

Mother Earth. Journal of the Soil Association. (Quarterly).

Health and the Soil. Edited by Dr. A. Campbell, Edinburgh.

Compost Club Magazine (published every two months by the New Zealand Humic Compost Club, Box 1303, Auckland).

Organic Gardening, Emmaus, Pa., U.S.A., published monthly.

REPRINTS

RAYNER, M. C., *The Mycorrhizal Habit in Crop Plants, with a reference to Cotton.* Empire Cotton Growing Corporation publication, reprinted from *Empire Cotton Growing Review,* Vol. XVI (3).

OTHER AUTHORITIES AND PUBLICATIONS ALSO REFERRED TO IN THE TEXT

BAKER and MARTIN, *266 Bakt II* (1937).

BUTLER, E. J., *The Occurrences and Systematic Position of the Vesicular-arbuscular Type of Mycorrhizal Fungi (Transactions of the British Mycological Society,* Vol. XXII, Parts 3 and 4, Feb. 1939).

DRECHSLER, DR. C., *Predaceous Fungi* (Biological Reviews, Vol. XVI, 1941).

GREENWELL, SIR B., *Journal of Farmers' Club* (1939).

McCARRISON, MAJ.-GEN. SIR R., *Journal of Medical Research* (Vol. XIV, p. 351, 1926).

----------, *Nutrition and National Health* (Faber and Faber, 1944).

McMILLAN, M., *The Nursery School* (Dent, 1930).

ORR, SIR J., *Food, Health and Income* (1936).

ROWLAND, DR. T., *Biochemical Journal* (Vol. XXIV (1), 1930).

P.E.P. REPORT ON THE BRITISH HEALTH SERVICES (1936).

WILSON, CAPT. R. G. M., Evidence before Lord Justice Scott Commission (1942).

WORLEY, PROFESSOR B., *The Poor Earth* (Wilson & Horton, Auckland, New Zealand, 1938).

GLOSSARY

AEROBIC, dependent upon air for life.

AMOEBA, a genus of microscopic Rhizopoda (see Rhizopod).

ANAEROBIC, capable of living in an atmosphere without oxygen.

ARBUSCULAR, tufted, shaped like an arbuscle (i.e. a dwarf tree).

BIONOMICS, dynamic biology. Bionomy = the science of the laws of life, or of living structure.

BLEPHARITIS, inflammation of the eyelid.

CAECUM, the blind gut. The first part of the large intestine which is prolonged into a cul de sac

CASH CROPS, any crop sold off the farm for cash, as opposed to one consumed on the farm by livestock.

DETRITUS, matter produced by the wearing away of exposed surfaces. An accumulation of disintegrated material or debris.

DIATHESIS, a constitutional predisposition (inherited or acquired).

ECOLOGY, that branch of biology which deals with the relations of living organisms to their surroundings and each other.

ECTO, outside.

EDAPHIC, pertaining to soil.

EMPIRICAL, method based on result of observation and experiment, not on scientific theory.

ENDO, within.

ENDOPHYTE, a plant growing within an animal or another plant.

ENDOTHELIUM, the tissue lining blood vessels, etc.

FRUMENTY, a country dish made of boiled whole wheat and milk.

HAUSTORIUM, the sucker of a parasitic plant or endophyte which penetrates the tissue of the host.

HISTOLOGY, that branch of anatomy which is concerned with the cell structure of the body.

HYPAE, see Mycelium.

INTER, between.

INTEA, on the inside.

LIGNIN, an organic substance which forms the characteristic part of wood cells, and woody fibres, making the greater part of the weight of most dry wood.

METABOLISM, the sum of the chemical changes within the body, or within any single cell of the body, by which the protoplasm is either renewed or changed to perform special functions, or else disorganized and prepared for excretion.

MORPHOLOGY, the science of the outer form and internal structure (without regard to function) of animals and plants.

MOTILE, capable of deliberate motion.

MYCELIUM, the vegetative system of fungi consists of filiform branched or unbranched cells called hypae. The hypae collectively form the mycelium.

MYCOLOGY, the science of fungi.

MYCORRHIZA, fungus mycelium which invests, and lives in association with, the roots of many plant species.

NEMATODE, a class of worms, having a mouth and an alimentary canal and separate sexes. Usually parasitic. Ex: round worm, threadworm, eelworm.

NODULE, a small knot or node in the stem or other part of the plant.

OTORRHOEA, a purulent discharge from the ear.

OPTIMAL (see Optimum).

OPTIMUM best.--temperature. That temperature at which the metabolic processes are carried on with the greatest activity.

PAN. An impervious layer in soil which interferes with the passage of air and water. Can occur at varying depths, and is due to a variety of causes.

RETICULUM, the network which pervades the substance of a cell and nucleus enclosing the softer portion of the protoplasm.

RHIZOPOD, the lowest class of protozoa (primitive animal organisms).

SCHLEROTIA, a compact mass of hypae (see Mycelium) in a dormant state.

SILAGE, feed for cattle made by preserving fresh green fodder by compression in a silo.

SOMATIC, pertaining to the body, or material organism as opposed to soul, spirit or mind.--death = death of the body as a whole, i.e. all the cells of the body, as opposed to death in any of its parts.

SPORANGIOL, small spore case.

SPOROPHORE, the spore-bearing organ of a fungus. Ex: mushroom, toadstool.

SYMBIOSIS, a living together of two organisms, each of which is necessary to the other.

TROPHIC, pertaining to nourishment, or nutrition.

VASCULAR, containing clearly defined vessels or ducts for the circulation of sap.

VESICLE, any small bladder-like structure, cavity, cell or the like, in a body.

XEROPHTHALMIA, dryness of the eyes.