The Earth's Green Carpet

by

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Faber and Faber Ltd
24 Russell Square
London

First published in Mcmxlvii
by Faber and Faber Limited
24 Russell Square London W.C.1
Printed in Great Britain by
Latimer Trend & Co Ltd Plymouth

Naturam expellas furca tamen usque recurret.
You may pitchfork Nature out but back she'll come again.

-- Horace

Preface

In presenting a short popular account of the ideas inspiring the work of her husband, Sir Albert Howard, formerly Director of the Institute of Plant Industry, Indore, and Agricultural Adviser to States in Central India and Rajputana, the author believes that she is satisfying a demand. She has not written for the specialist nor is she competent to do so; but she joins herself to those who without being scientists are yet interested in the use made by mankind of the rich mantle of verdure which covers the earth and which is the source of our food and most of our raw materials. There exists a deep conviction that this use should be a wise one and a right one.

Sir Albert Howard's work stands out by reason of his recognition of this truth. What he advocates goes far beyond the immediate interests of the farmer or of the agricultural research worker. His ideas have developed gradually, most rapidly perhaps in recent years, when surprising points of view presented themselves; indeed, the advance has lately been so sweeping that by the time it has reached the public each book written by him seems behind the development of his thought. These books have attracted readers in all parts of the world and are notably influencing the practice of agriculture. But not even these books and all his other writings and speeches taken together give quite the full message of his genius, which seems to flow more richly and gather more force by very reason of the constant living response which it is evoking in others.

Thus there has come into being a school of thought inspired by his leadership, which has chosen to call itself the School of Organic Farming and Gardening, though more is involved than this expression implies; the title is convenient but nothing more. Of this school there are many I distinguished exponents. Its characteristic qualities are courage, cheerfulness and the willingness to dare. A break has been made away from the doubt and uncertainty which for a half a century have prevailed both among practical farmers and scientists: the reformers do not see why agriculture should be unsuccessful nor why it should be so despondent. They believe the earth can be cultivated, that it can be cultivated properly, and cultivated prosperously. They base this belief both on scientific argument and knowledge and on very successful pioneering experiments.

It has been the greatest asset of their leader that in the course of his long life he has been able to weld three things together: a natural love of farming inherited by blood and nursed in boyhood; a severe and comprehensive scientific training which went far beyond the subjects immediately associated with agriculture; and a prolonged period of work in the East. On the last point stress may be laid. In spite of our boasted research and scientific advances it is by no means certain that our Western cultivation of the earth's surface equals that of the Eastern races; in many directions we have much to learn and certainly something to unlearn. Moreover, the effects of tropical or sub-tropical climates are such that only by residence in such climates can a clear idea be gained of the working of natural law: results are immediate and unmistakable, and the scientist is led, almost against his will, to recognize much that is obscured in more changeable and milder zones. A residence among the Eastern races in some tropical country should therefore be part of the training of every scientist who wishes to devote his knowledge to agriculture.

Such residence would teach above all things respect, respect for Nature but also respect for ancient human experience. It would burst once for all the narrow confines within which the agricultural research worker has lately chosen to restrict himself; it would take him into the fields and among the peasants and would save him from the condition of being a laboratory hermit which at present seems to be the ideal of so many. It is regretted that in the present short book there has been no opportunity of developing Sir Albert Howard's trenchant views on the present state of agricultural research, views which, if they could gain the acceptance which they merit, would bring about as great a reform in the formal scientific world as has been initiated in the world of farming by his campaign for fertile soil.

For it is to the thesis of a fertile soil that every argument and every practice reverts. This would be the possession of all races and all peoples. The principles underlying the demand for the restoration and maintenance of soil fertility admit of no frontiers and laugh at political and economic perplexities; some hopeful minds believe that many existing difficulties of this nature would vanish if we could learn to cultivate Mother Earth rightly, feed ourselves properly and insist on a free exchange between the nations of the direct and indirect products of sunlight. However that may be, it is certain that some respectable advances would be made in human welfare. In the belief that this is the concern of all, whether knowing anything or nothing about science and about agriculture, the author presents her book to the public.

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The Earth's Green Carpet

By Louise E. Howard

Part 1
General Principles

Chapter 1
The Wheel of Life

The first thing that strikes us about the. earth's green carpet is its variety. Though generations have passed and many thousands of books have been written since we began to take systematic note of the forms of vegetable life we are still engaged in this task. To describe merely the different colours and shapes of leaves and petals could fill volumes; the range of size from invisible bacteria to a vegetable organism of the stature of an oak is immense; differences in structure and habit are dramatic. This rich abundance of forms, shapes and values is insistent to our eyes and mind. What at first sight we do not remember is the extraordinary stability behind this natural variety. It is almost impossible to deflect Nature; it is quite impossible to throw her finally out of gear. This stability expressed is the very basis of natural law.

The earth's green carpet: for how many millions of years has it not continued? It may have changed; desert, swamp, forest may invade this or that sweep of country; long slow climatic alterations may have affected the vegetation of whole zones. But how unalterable it is in its essential nature! It is maintained generation after generation, unimpaired, not really controlled by any efforts on our part, with powers of defying us and powers of renewal which are a philosopher's commonplace -- the weed that springs on the deserted path, the ivy that invades the abandoned house, the ubiquitous blade of grass that inserts itself even into the smallest crevice of the close-set pavement. There is a power here, a continuity which laughs at us, which is so utterly superior to what we can build or make safe that it is quite beyond measurement in terms of human endeavor. It forms part of our existence: we accept it: we are sure it will not be destroyed.

The process repeated over millions of years of the dying-down of the green carpet and its renewal is something wonderful. It is secured only because Nature has the unalterable habit of returning to her soil -- whence all life springs -- all her wastes. This she never omits. Nothing in Nature's green carpet is thrown away; nothing is discarded. There is a regular and uninterrupted cycle which never stops. Nature practices complete continuity and complete conservation. We speak of the wastes of Nature, but there are no wastes; there are no dust bins, no sewers and no rubbish heaps; there is only a scattering of material, a fresh collection and a transformation.

When the higher organism as we know it -- the plant or animal -- dies, it does not cease to take its place in the natural cycle. The moment of death is the signal for a long series of changes in the materials making up its body; these changes are living processes. They signalize the breakdown from something highly intricate to simpler and simpler forms of life, but they are very gradual, through various forms of invertebrates to fungoid or bacterial existence, and thence again through many intermediate phases to the final mineralized or inorganic stage, from which at last a new ascent can begin via the sap of the plant, which is partly fed from the plant roots absorbing these minerals. Thus the cycle runs through many forms of physiological, chemical and mineral activity, a very wide, prolonged history, the breadth, depth and intensity of which it will be well to note even at this stage of our description.

This is the process on which is based the renewal of the earth's green carpet; we may call it the Law of Return.

Every phase of it is going on everywhere at all times, and it is this ubiquity and what we may term its non-stop character which pervades everything. The shocks and natural cataclysms which seem so violent -- storms, floods, eruptions, whatever they may be -- are trivial against this immense background. Such disasters stop nothing; they merely activate some special fresh phase of the natural round, which goes on unceasingly out of the enormous accumulation of materials. For the neverceasing character of the return of all wastes insures a stupendous margin of safety; a huge reserve system is another feature of Nature's working.

These reserves are stored in a number of ways. We know that the atmosphere holds unlimited volumes of oxygen and nitrogen, that the oceans, streams and clouds contain vast masses of water; and so on. There is a more intimate storing of reserve in our own bodies and in the bodies of animals; these reserves, which include organized food reserves, enable us to withstand shock and illness. Plants do the same thing; they store what they need to enable them to withstand drought, cold and starvation. They in their turn have obtained some of the raw materials for these from the vast reservoir which is present in the subsoil, between which and the topsoil there is a continuous circulation. There is a storage system right through Nature, and it may in effect be said that there is nothing natural existing which is not insured and reinsured many times over.

It is above all the top layer of the earth's crust which constitutes the pre-eminent reserve of Nature. Here are caught and held, and *transformed*, the substances which build up fertility, that particular soil factor of which we know the meaning and significance quite well, even though scientists declare themselves unable to give it an exact definition. The top layer of our earth is indeed the factor on which we must fix our careful attention if we wish to understand the working of natural law. These few precious inches of soil, to which we shall have frequent occasion to refer, are the very crux of the matter. They are the habitat of, they embrace and create the vast stores of original living material from which our planetary existence is derived.

It would almost appear as though Nature herself held this top layer very precious, so careful is she to anchor it firmly in its place. It is fixed without serious risk of destruction by the vegetation which springs from it -- the earth's green carpet. What is interesting is to see the adaptation undertaken to suit the character of the soils created. This is part of that principle of variety which we noted, a variety not capricious but carefully planned and calculated. We do not, in our country, perceive this at once, because Nature is seldom allowed a free hand. But where she is -- and she is forever escaping our controls -- it is obvious. A few years' neglect of a cultivated field will see, first, what we call weeds spring up; a little more, and the hedges will begin to grow out -- the hedgerow flowers themselves are an ever-present example of Nature's independent and both selective and varied choice of the smaller flora for a temperate zone. Then if neglect were continued, scrub would cover the whole field, and finally forest. In temperate climates with good rainfall forest is what is known as the ultimate succession, i.e. the final covering which Nature would consider the most suitable to the circumstances. Elsewhere, for instance, where there are greater extremes of drought, we should find a grass covering -- the steppe; where there might run an accumulation of subsoil water, we should find marsh vegetation, in a desert we should find plants like the cactus. The adaptation also depends on elevation, as is very easily observed in ascending or descending the mountain-side.

These adaptations are very remarkable in their detailed singular perfection. Even a schoolboy will know that certain wild flowers and fruits will grow in one spot and not in another; they are a known factor in farming -- the farmer expects to reckon with the different capacities of his different fields. Adaptation is the result of Nature's fitting the instrument of the living plant to the living soil; for plant and soil are geared together -- they are a single world, and as such they must be throughout regarded by the true observer.

This law of adaptation applied to soil and vegetation is closely supplemented and indeed continued by another great principle -- the principle of mixed existence. Look at what appears to be a uniform bit of meadow grass -- there are dozens of different plants included in the making-up of the sward; within the space of a few inches a whole series of specimens may be found. They jostle and fight each other, and as the season advances fresh varieties appear; there is so great a pressure that often a week or two or even a few days only are allotted to each variety for its growth and blooming; it falls, and is instantly succeeded by something different. The competition is carried on by every type of plant; herbage, bush, creeper, tree, moss, lichen, fungus, orchid, all intermingling their manifold lives and simultaneous in their striving for their share of light and nourishment. At no moment is the victory to a single type. However uniform even the most monotonous forest or steppe may seem, there is always an abundant confusion of vegetation included in its apparent sameness, at first unsuspected but on the slightest examination amazing and rich.

The principle goes farther. Nature has laid down that there shall be no separate vegetable and animal existences; these two kingdoms are to be one kingdom. This is perhaps the most important truth which we have to bear in mind in the course of our brief survey of natural law. It is too often ignored, but it is a fatal error not to realize how basic to all continued physical health and prosperity is the dwelling together of the vegetable and the animal. The animal, it is obvious, does not exist without the plant, which directly, or in the case of carnivorous animals indirectly, constitutes its food; but neither does the vegetable exist without the animal.

It is unheard of in Nature to attempt any type of vegetable growth without the enrichment supplied by animal existences. Such animal life may be in the form only of insects or invertebrates, but it is never omitted, and is usually most abundant. The most silent, the most deserted countryside is teeming with it. The mode of enrichment is to be noted. Both the excreta of the animal when living, and also its body when dead are absolutely essential to the continuation of vegetable growth. In the aggregate the natural collection of these substances is of colossal proportions.

They do not act directly on the plant. Except in the case of a very few insect-devouring plants, there is no mechanism by means of which the vegetable can absorb animal substances as such. They have first to be dealt with, and the processes for doing so are just those processes of decay and prolonged transformations which we have already stated to take place on and in the top layers of the earth's soil -- those layers which we have called the crux of everything. When these few inches have done their work, this perfect section of the natural round has run its allotted revolution, then all is ready, and the rich green carpet so familiar to us is the reward of these processes, so delicate, so intricate, and yet so strong.

Perhaps the fact that the plant has to wait for its food materials may teach us something about yet another factor -- the working pace of Nature, her tempo, so to say. This may be described as unhurried or deliberate rather than actually slow. We are fairly accustomed to observe this; though the smaller simpler existences multiply sometimes at a terrific rate, it is more common for us to dwell on the time taken for growth even of a humble cabbage, while the life-period of a tree stretches out both behind and beyond our own lives. Animals illustrate the same law; they are mostly somewhat slow in their growth, and the higher their nature, the more noticeable this is; the long period required by man before he reaches physical maturity is a remarkable fact, and most vertebrate animals have a set period of infancy and youth, not so protracted as our own, but long enough. When we contemplate the major operations of Nature, where the quickening element of life is absent, we find great deliberation; the disintegration of rocks, or the opposite process, the building up of new land, are gradual processes, varying enormously, no doubt, in the time periods over which they consummate themselves, but seldom to be described as rapid.

This pace set by Nature is to be noted, because we shall presently have to consider how far it is within our powers to vary it; and we shall also have to consider how long Nature is going to take to make good the errors we commit when we are too impatient in doing so. There is nowadays much talk among scientists about accelerating natural processes; quick habits of growth and ripening are sought, and the idea has even invaded the animal field. The subject is, therefore, of importance, but the only point to be made here is to grasp the fact that natural processes have their own tempo, and that, on the whole, this tempo is not to be described as a quick one.

Infinite variety, a stability founded on the accumulation of reserves, an intimate gearing together, in the first place of the soil and the plant, in the second place of the plant and the animal, and a final return of everything, all processes carried on at an unhurried undeflected pace, these are the characteristics of the natural round, the laws which keep our world alive.

Thus far we may follow and understand; but not farther, We can apprehend these laws and obey them; but we cannot explain the result. The fact that constitutes what we call life will probably always baffle us. We know it, we see it, we feel it, but it eludes us. Although so persistent and pervading, so much a part of ourselves, it is not within our mastery. We can neither create it nor exactly define it.

We can, however, in an indirect way say a good deal about it. It is certain that it includes a very long progression from lower to higher. This progression or chain begins right back with some form of energy, emerges, after a long history of which we begin to know a little, as the atom and then as the combination of atoms or molecules, passes from the inert mineral stage to chemical action, reaches the biological phase, appears as an animalcule or similar simple body, and then as an organized species, vegetable or animal, and finally as man. The transition is throughout gradual, often imperceptible; there are many mineral and physical processes; there are complicated chemical transmutations; then about halfway along the chain biological action follows chemical so closely that we are forced to recognize a stage which we call bio-chemical; subsequently it is hard to say where the vegetable ends and the animal begins; but somehow, somewhere in this long transition life is born.

It is a curious fact that we, being placed at the farthest end of the chain, have the capacity to look backwards and survey its whole length. This is what constitutes the characteristic of human thought. What do we see? In the first place and above all an upward trend, as has, indeed, already been implied. This advance or upward trend has profoundly impressed itself on our imagination, or perhaps, to speak more accurately, on the imagination of the Western races; in contemplating this advance we lay great stress on the living or dynamic principle. Science, which is the product of the Western mind, has taught us to picture existence as an inclined plane, a sort of staircase or ladder, leading ever forward and ever higher. This fits well with the character of Western religions, which themselves perhaps derive something from this physical presentation; the formula and the hope of the upward trend is prolonged into the spiritual sphere. Optimism and courage are the fine reward of this most inspired conception and have rendered untold service in the shaping of our Western civilization.

Yet something has been lost. In evolving the stimulating conception of continuous advance some portion of the truth has had to be sacrificed. A very small amount of reflection will restore it, for it is not really forgotten, only obscured. To restore the balance of our ideas it will be useful to take an image which is common to Eastern thought, and instead of thinking of life, i.e. physical life, as a ladder or ascent, to think of it as a revolving wheel.

The Wheel of Life is a well-known Buddhist symbol, and it has this merit -- it restores to its proper place that other half of physical reality which we Westerners rather carelessly group together as the process of decay and death. We rather carelessly group these together and promptly forget them, only assigning a place, as needs we must, to the undeniable fact of death, which balances the fact of life and is equally inexplicable. But the interim processes, the long stages which prepare for and contribute to that consummate final act, are far less interesting to us than the stages which lead up to birth and contribute to growth and increase; we tend to ignore them.

This pronounced distaste is not unnatural in creatures conscious of enjoying life. It leads, however, to a slightly distorted view of physical realities. Too much attention is focused on the exciting phenomena of growth and reproduction, too little on the processes of decay and dissolution. The odd thing is that properly examined these latter processes are as intense, as intricate, as exciting as any that precede them; that they are themselves living processes, life; there is not, in fact, any difference in principle between them and the birth and growth of the higher organisms. It is simply that one set of phenomena easily strikes our imagination and is commonly visually perceptible, the other is hidden and not generally perceptible to the eye, might, ignorantly, be termed secret.

They are the other half of the Wheel; the half that revolves away from us, whirls round out of our sight, and emerges again at our feet to begin the upward sweep. The image of the Wheel is really very good and may well be kept in mind. A Wheel, moreover, can run true or can be thrown out of balance; on this also we may reflect. Lastly, let it be added that Buddhist philosophy has invented a very complete set of punishments, a merciless and unrelenting hell, for all who refuse to conform to the Wheel's motion.

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Chapter 2
Growth of the Plant

In a wheel that revolves evenly and without intermission it is difficult to find a starting point; every point is a beginning. The more carefully we look at the natural round the more we become conscious of the ceaseless character of its revolutions. Yet if a point must be chosen at which to make our first reflections, we cannot do better than choose the green leaf.

This wonderful mechanism is unique. The green leaf has the extraordinary capacity of securing the transformation of dead matter from the inorganic to the organic condition. It does this by changing simple mineral and chemical compounds into protoplasm which means living substance, so that we may say that if anything creates life on our planet it is the green leaf. Nothing else in Nature can do this. Were the green leaf to fail us, our civilization and culture would fade into nothingness, our existence would cease to have an origin, we ourselves should perish.

It operates by using the energy of sunlight. On this everything depends. The explanation of this process is very profound and to a large extent still hidden from us, but we may roughly say that the green leaf combines physics and chemistry in an act of creation, and that the created thing is organic matter in the shape of food -- food for the plant, food for the animal, and food for man. Every green leaf contains a substance called chlorophyll, which enables it to intercept the energy of light and perform this miracle of transmutation. Our own recent boasts about our extensive use of atomic energy are petty compared with this marvel, which has been going on for millions of years. There is no comparison, nor ever can be, between our puny strivings and the operations silently carried on by the plant world, operations massive, perpetual and universal. The work of the green leaf is the master process and the master secret of the world.

As is obvious, the leaf is part of a larger structure; we shall not be able to follow what the leaf does unless we know something of the whole organism, the plant. In plants is exemplified in a high degree that natural variety which we noted in our first chapter. The size of plants alone ranges from an alga so minute as to constitute, even when repeated a thousandfold, a mere green smudge on the surface of something else to a huge tree like an oak, which from its crown to its deepest root may measure two hundred feet and whose weight may run into many tons. Differences in shape, pattern, function and length of existence are no less; did we not know it we might be inclined to deny the identity of the daisy, the potato, the sugar cane, the apple tree, the vine, the fern, the elm, the coconut palm, to take at random a few examples of varied plant life. Yet we have no real difficulty in recognizing among all these variations a common obedience to the same laws. They are all rooted in the soil; they all seek air; they all grow; they all need the same food materials; this defines them as a single group of created things of like nature and function.

Their most obvious characteristic is their capacity for growth, for rapid growth, and in many cases for renewed growth. There is a great strength in this, surpassing what the animal can display, which unlike the plant does not easily survive great interference or injury and which certainly lacks the ability of so many plants to die down -half the year and spring up again more strongly than before with the return of the season. This persistent renewal of the plant is derived from its genius for finding and making its own food out of the most unpromising raw materials and sometimes despite the most unpromising circumstances. It is this food factory we propose to examine in the present chapter.

The plant draws the raw materials for its food from everywhere. It draws from the atmosphere; it draws from the soil, namely, from the gases in the soil, from the mineral particles therein, from the organic matter there, from certain forms of fungi (which are themselves also part of the plant world), it draws from water. A very few plants are piratical and feed on other plants and a few rare species feed direct on insects, but most plants are content with these three normal sources of food material, the air, the soil, the waters. Their mechanisms for searching out raw materials are by now highly developed and more than one alternative method of absorbing these materials has been acquired; plants are, so to say, insured against all risks. This is an important point.

On the whole, the sources of the food materials at the disposal of the plant are inexhaustible. Their availability is another matter. It often happens that the needed substances are there but that the plant is unable to use them. Either they are out of range or the plant is unable to exercise the capacity for taking them in. In cultivation by man this availability of the plant's requisites matters enormously.

The higher plants consist of two well-defined parts, one above and the other below ground. Both of these parts take in not food, but raw materials for making food; the real food always has to be manufactured by the plant itself for its own support; this is the great difference between plants and animals, for animals must find their food in a form which they can directly digest, even if, as in the case of ruminants, the digestion processes are prolonged. In order to have access to as much food material as possible the plant stem and branches above ground, the main and lateral roots below ground are spread out in such a way as to bring the leaves and the rootlets and root hairs, which are the agencies for gathering in the supplies, into contact with as much air space and soil space as possible; these fine instruments then comb their respective mediums for what they can get; there is not a square inch left unsearched. Moreover, each of these systems enters into further competition with the similar systems of other plants. Thus there is a great jostling for available food materials both in the air and in the soil. In the air every possibility of the sunlight is explored by Nature by the simple device of allowing different plants to attain different height levels and also by causing the general leaf canopy to develop not simultaneously but in successive stages; thus the mosses at the roots of the forest tree will be very bright green in the early spring, while they can still get the light before the higher tree foliage shades them-for that brief space it is their hour. In the same way the various layers of the soil are combed by the rival root systems at successive intervals and to successive depths. It is also known that plants withdraw slightly different constituents from the soil and that possibly they may help each other in some way to do this.

As far as possible the farmer must manipulate his crop to follow this intricate pattern in the plant's search for food materials. It is by no means always easy, and one of the risks of human cultivation is that too many of the same plant may be sown, growing simultaneously to an equal height and depth, thus leaving much air space and much soil space unused, and also drawing away too much of the same kind of raw material.

When completely nourished a plant is made up of water, which forms no less than 80 per cent of its structure and keeps it turgid and erect and thus able to reach the right level of height; of a number of complex organic substances; of a number of different mineral salts; and of proteins, which are in truth the most important of all. Of these constituents water is the only one which is absorbed by the plant, so to say, ready-made. All other materials, as we must repeat, have to undergo processes of manufacture within the plant.

The necessity of water for a plant needs no argument. It is obvious; without water no plant can grow. As we shall see presently, water is also the vehicle for conveying to the plant a large part of its food materials and for moving about the food when made. It might almost be said that the art of causing plants to grow is comprised in the art of giving them water in the right way; there is a great deal of skill in doing this. It has been argued that the Western nations in their cultivation are extravagant in their use of water, perhaps because it is so abundant. In the East water is used with more care and far more effectively.

One thing we find very hard to manage and that is the giving of water which is not merely sufficient in itself and rightly distributed, but which holds oxygen in solution, that is what rain consists of. As it comes down it washes out some of the oxygen in the air and dissolves it; it becomes highly impregnated. This makes it so extraordinarily refreshing. Now the roots of plants need oxygen as much as they need water, for oxygen gives the plant an essential factor for carrying on its manufacture of food. The rain is one important source from which the plant derives its oxygen.

The other is the atmosphere. That is why air, whether above or below ground, is the second great essential to plant growth. Plants must breathe, though, as we shall see presently, they do this in a way differing from that of animals. They need air, however, as much as any animal. Thus water and air are the two prerequisites of the growth of a plant; they condition the intake of all other raw materials. Even a partial deficiency in either causes plant life to sink to a low level. Lack of water produces the desert with its scanty bushes, lack of air produces the marsh with its depressed forms of vegetation.

We stated above that the green leaf has the faculty of absorbing its raw materials and causing them to combine within itself, and that these substances have to be simple or nearly simple elements. This at once introduces a limitation. Contrary to what we might at first suppose, the plant cannot feed immediately off anything in the soil. The soil has to do its part also. It is impossible to understand the growth of the plant unless we have some idea of the life of the soil. The plant cannot, for instance, absorb inert minerals except by a sucking action -- osmosis -- they have therefore to be dissolved. Nor can it find its food direct either from decaying matter or from animal excreta; it has to wait until these substances have been prepared for it. In fact, the plant world which supplies us and all other animals with abundant food to eat is, in this respect, dependent on yet a third group of created things to supply its own needs. This group is the soil flora, the great soil proletariat, as it has been called. The soil flora, as its name implies, is itself in some ways like a growth of plants; in other ways it more resembles a swarm of tiny insects, but its components are so ultra-minute -- they are described in science as microflora -- that it is rather futile to institute such decriptions. The soil flora has one thing, however, in common with the plant world; it is exceedingly varied. This applies both to the soil fungi, which are really themselves forms of plants, mostly very minute, and also to the soil bacteria, which are quite invisible to the naked eye. A number of families, genera and species of both fungi and bacteria have been classified and examined; they have different functions to perform, sometimes successive to each other, but often in competition. This soil flora, it will be realized, is alive.

In breaking down the organic matter in the soil the fungi act first. They can be seen as tiny threads of grey matter clinging to dead roots and twigs; they attack this mineral and thrive and multiply on what they find. The bacteria succeed them and complete the process as the second agents. They incorporate into themselves much of what they eat and form microbial protein (the fungi also have a high protein content); at the same time they manufacture as an end product the inert mineral salts, largely nitrates with some phosphates, potash and so forth, which form a portion of the food materials of plants. It is at this point that the Wheel of Life revolves at its lowest; it is here that what was once living is being reduced to what is inert and inorganic. The soil flora are the selected agents for this devolution, which only the plant can reverse.

When the microflora have done their work there is a most varied assortment of substances in the soil. There are the original soil elements -- these occur as constituents of a variety of minerals in conformity with the general composition of the underlying rocks and of the subsoil from which the topsoil was originally derived; there are quantities of undecayed organic waste; there are the mineral salts to which the fungi and bacteria have finally reduced the remainder of these wastes, and these exist in every stage of their descent to the inorganic phase; there are the fungi and bacteria themselves, active, and at work; and there are their bodies when dead, amalgamated with the undecayed portions of the vegetable and animal wastes in the form of humus.

This mass is not without a system. The soil water is the great binding agent which unites it all. The soil water is the habitat of the soil microflora which actually live in it. It takes the form of a thin film of moisture bathing each soil particle. The water which makes it up is derived both from above and from below; from above by the percolation of the rain, from below by the rise of the subsoil water through capillary action. The soil water is in constant slow movement; it is also impregnated with that dissolved oxygen which we noted as washed down by the rain out of the atmosphere and this oxygen is drawn on by the soil flora when they manufacture their nitrates and other compounds. The supply of oxygen is therefore as important to the soil flora as it is to the plant. If the soil solution is fully oxygenated and moving, conditions are favourable to the life of the soil; if it is deprived of oxygen and stagnant, there is a great slowing down in the activity of the soil inhabitants.

'The soil solution, however, is not simply oxygenated water. Besides oxygen it also holds dissolved carbon dioxide. This is derived in part from the air but mostly from the fermentation of organic wastes, a process which always produces this gas. By absorbing carbon dioxide the soil solution becomes slightly acid, and it is this mildly acid character which enables it to perform the important function of the dissolving of minerals. Both the original mineral elements in the soil, and also the compounds which the fungi and bacteria have produced out of the organic wastes, are then easily held dissolved in the soil solution.

It will be seen from this account that the state of the soil solution, as regards its impregnation both with organic compounds and also with minerals, depends on there being organic matter giving off carbon dioxide in the soil. It is particularly important to note that the soil solution is unlikely to be richly impregnated with minerals unless it is also in contact with an abundant supply of decaying organic matter. It has not the power to dissolve the minerals unless it can attain the necessary slight degree of acidity given by the continuous absorption of carbon dioxide. Any idea that the soil solution can be mineral-rich without being also organically supplied to an ample degree is futile.

It is the soil solution which is the vehicle for transferring the food materials in the soil to the plant. It is sucked in by the root hairs (osmosis), entering through the cellulose walls, carrying both water and supplies of the materials which the plant needs to manufacture its own food. This is the straightforward and obvious way in which plants derive their raw materials from the soil.

But there is a good deal more to be considered. The soil solution does not by any means satisfy the needs of the plants. It has to draw on other resources, more especially on the atmosphere; it has also to draw on the soil itself in rather more special ways. While the soil solution gives it part of its food materials, namely, organic compounds and inert salts, it also needs large supplies of carbon and some extra nitrogen. In fact, the range of food materials which the plant requires is surprising; it needs most of the important elements and many of the rarer ones. Into this wider question we cannot enter, and shall do well to conclude by concentrating briefly on its need for the two elements just named, carbon and nitrogen.

Carbon is one of the first requirements of the plant as it is of all living things, forming, as it does, the core of the material structure of all that we see around us. To obtain carbon the leaves of a plant breathe in carbon dioxide gas from the atmosphere; the chlorophyll of the plant, using the energy of light during the day, builds up this gas into the food on which the plant lives -- carbohydrates, proteins and so forth. These carbohydrates and proteins not only feed the plant but they have a subsequent career of their own; they are the only source of food on this planet, they feed the animals and ourselves. The atmospheric supply of the carbon dioxide needed by the plant is a product of the respiration of animals (and also in part of plants themselves); animals breathe in the oxygen of the air, use it to burn up slowly the food in their own bodies and then exhale this carbon dioxide. The green leaves also give out oxygen, the source of which is still undetermined. The old idea was that this came from the carbon dioxide of the air, but recently it has been suggested that the source is water. The processes of the plant and animal are thus reversed during a large part of the twenty-four hours.

This means that there is a perpetual circulation of carbon dioxide, ensuing the circulation of carbon, in and out of the atmosphere, the plant balancing what the animal does, or, if we like to say so, purifying the atmosphere vitiated by the animal. Were this not so, were plants not there to remove the carbon dioxide, this gas would accumulate in the air and we could no longer keep alive. This is the first great interlocking act of the plant and animal world in Nature, the first point at which these two groups fit into and supplement each other's functions.

Although the atmosphere only contains 4 parts of carbon dioxide by volume in every 10,000, this is sufficient; there is no carbon problem for plants. This means that there is no carbon problem for any of the other living things in Nature. We must never forget that it is the plant and sunlight which secure the carbon needed out of this inexhaustible atmospheric supply, and which start it on its career in the organic phase, thus enabling the structures and bodies of all created things to build themselves up into solid forms.

The problem of nitrogen is quite different. It is curious that this singularly inert gas should be the basis of the life-principle. There is a surpassing need for it in all living things. Nitrogen is required to form the proteins, and these, as we shall constantly have to emphasize, are the substances which hold the secret of growth, health, well-being and reproductive power. It is not surprising, therefore, that every source of nitrogen which can be found should be called upon. There are three sources: first the nitrogen existing as gas in the atmosphere, which is known as uncombined nitrogen or free nitrogen; second, the nitrogen existing as organic compounds either in decaying matter in the soil or in the dropped excreta of animals; and, third, the nitrogen existing as inorganic compounds resulting from the final breakdown of these two materials; both the last forms of nitrogen are usually referred to as combined nitrogen because they exist in combination with other elements.

The plant has some difficulty in assimilating any of this nitrogen. As we have seen it has to wait for the soil flora to break down the organic wastes, and then has to wait further for the soil solution to dissolve the products thus produced; only when all this has been done can it get at these food materials. It is therefore scarcely surprising to find that plants can be starved of combined nitrogen. This shows itself in a stunted condition, in paleness of colour, in general weakness, and finally in failure of reproductive power. It is also possible by human agency to supply plants with too much nitrogen, which betrays itself in a superabundance of rank foliage and very dark unnatural colour, but perhaps this is a question which need hardly be considered at this point. That plants in a natural condition have something of a struggle for nitrogen may be admitted, and it is interesting to follow the special mechanisms which some of them have evolved to obtain extra amounts. What is present in the soil is an item for competition between plant and plant, so that any extra supplies to be obtained have to be looked for from the inexhaustible volumes present in the atmosphere.

Can plants absorb something from these inexhaustible volumes? If they could, their life would be easy, for the supply is super-abundant, namely, 75 per cent of the total volume of the atmosphere. But only a few plants, and algae and some other low minute forms of vegetation like lichens, can absorb the free atmospheric nitrogen-this process is known as nitrogen fixation. Nevertheless, though exceptional, the capacity which they exercise is important. When such plants die, the nitrogen they have collected in the organic condition is added to the nitrogen reserve in the soil, and this can be a material help to a succeeding crop. This process is not cumulative; the extra nitrogen may be lost again by a process of denitrification. But for the time being the collection made by these forms of vegetation can constitute an important addition to available supplies.

Exactly the same thing is done by a certain group of soil bacteria; these are known as *Azotobacter*. The *Azotobacter* also can fix nitrogen from the air and add it to the soil. These bacteria are most active in well-aerated fertile soil containing a sufficiency of carbonate of lime, which means that a soil already well supplied with what the plant wants will be able to find those extra sources of combined nitrogen, whereas a soil already infertile will not be able to get at them. The plant can profit by the result. It can also evolve a mechanism of its own, which, however, applies only to a certain group of plants, the legumes. These have acquired the faculty of growing on their roots, sometimes also on their stems, nodules, which look like tiny balls or buttons visible to the eye; these nodules are homes for colonies of *Bacillus radicicola*, in which there collect the free nitrogen of the air and store it in the combined form. Such plants come to carry banks of extra nitrogen on themselves, and again these reserves can help other crops. In wild life a certain number of such leguminous plants like the wild white clover are always in existence and add to the richness of the earth's green carpet; in our own cultivation processes it has become customary to include such a crop in our rotations for the purpose of getting the advantage of the extra nitrogen; this is added to the soil by means of digging in the haulms of the nodule-bearing plant, for instance, peas or beans. (This practice is discussed in Chapter 6.)

There is one other way in which plants absorb extra nitrogen, and it is quite a distinct one, for the nitrogen taken in is already in the form of living protein. Thus the rule by which the plant undertakes the manufacture of its own food is abandoned, and most exceptionally it consents to feed off something which has been made for it. This substance is a fungus or, to use the scientific term, a *mycelium*, which starts as an independent web-like growth, visible to the eye, surrounding the sheath of the plant rootlet, goes on to penetrate the walls of the rootlet which it has first surrounded and then entered. The *mycelium* has a very high protein content, i.e. a very high nitrogen content.

This curious process, which is known as a "mycorrhizal association" from the two Greek words for *fungus* and *root*, is common to a great number of plants; where it does riot occur it would appear to be replaced by parallel but even more intricate arrangements for the intake of proteins. It ranks as a *symbiosis*, i.e. as a living together, a true partnership, for the fungus and the plant eventually terminating the arrangement. We shall have occasion to discuss its full bearing later. Here it is enough to rank it as a significant method employed by the plant to get at a supply of extra combined nitrogen, and what is more at a very special form of nitrogen -- a method which is unique in itself and again one additional to the ordinary processes used by the plant to obtain this element.

The co-existence of these different ways of getting at nitrogen tell their own story; they show the plant's need. If plants may be said to jostle and fight each other for sunlight and air and water in a rivalry which can be deadly, they are equally_ pertinacious in competing without mercy for the available supplies of nitrogen.

It will have been realized by now that the growth of plants is a highly organized affair. Their ways of getting raw food materials are varied; they are at once greedy and fastidious collectors. Thus their relationships with their environment come to be intricate; they have one set of contacts with the atmosphere -- and these in themselves are not simple -- other contacts with the soil solution and the supply of water, and yet other contacts with the soil and all it contains. In three different directions they are at work, having to change their performance continuously, rapidly, and effectively with alterations in light, fluctuations in temperature, and according to the presence or absence of moisture. Perhaps the point on which most stress needs to be laid, partly because at first it might escape notice, is the relation of plants to the soil microflora. This relation is truly dynamic. Both plants and soil microflora are alive; both therefore need certain elements, oxygen, carbon, nitrogen. The passing to and fro of the last named is. extraordinarily complicated -- we have barely indicated a small part of what goes on. It is easiest to say, once for all, that plants and microflora, operating as they do in the same medium and simultaneously, mutually dependent on each other's results and yet capable of being in rivalry, are like two cogwheels in the same system which are closely geared together, the slightest movement in the one inevitably setting up a consequential movement in the other. The life of the soil and the plant are a series of dramatic sequences of which we see the result in the growth of the green leaf.

Of the importance of the function of that green leaf there can be no doubt; on the continuance of the earth's green carpet all that we are depends.

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Small farms

The Earth's Green Carpet

By Louise E. Howard

Chapter 3
The Agricultural Effort and its Reward

Man's existence depends on the use he makes of the earth's green carpet; his food is derived therefrom and from no other source. Primitive man lived first by hunting and fishing, this mode of living apparently preceding all others. But inasmuch as what is hunted or caught by hook and net itself feeds directly or indirectly on the green carpet, this constitutes no exception to our statement. There are surviving examples of this way of life, which, when practiced, is estimated to support one human family to every forty square miles.

The first step forward was an improvement on hunting. Animal flocks and herds were not pursued but assembled and allowed to breed; their human guardians followed them and lived from them, showing in this a wisdom which we may still admire. Sometimes the milk, sometimes the meat, often both, occasionally the blood of the animal, constitute the food which is derived from this pastoral way of life, which is always communal, because only a whole community can look after so many beasts; and indeed this sort of existence has given rise to some beautiful forms of communal civilization. Nevertheless, in essence this mode of living is only a harvesting or gathering up process; the flocks and herds continue their lives in a natural way; they may be driven from place to place in search of the vegetable substance which is required for their upkeep, but nothing is done to maintain these vegetable crops themselves -- all is left to the bounty of Nature, which provides the alternate summer and winter pastures needed. So rich is this bounty, so wonderful is the earth's green carpet, that human communities may exist in this manner for centuries. The never failing renewal of Nature sustains and supports them.

Parallel to this method of maintaining existence by pursuit or nurture of animals came the gathering of vegetable crops off the ground. At first these were wild, as the first animals eaten had been wild; berries or fruits were found and consumed. But primitive communities soon begin to be dissatisfied with what they may find in the course of their strayings; they strive to invent means by which they can see to it that such supplies shall exist in certainty. It is one of the greatest steps forward in all human history when crops are not collected but cultivated; then agriculture begins.

Perhaps because an actual interference with the soil, the base of all living processes, is a more violent intrusion into the natural cycle than the simple driving and milking and care of animals it seems to have been initially more difficult to carry out in a proper way than the pastoral life. Animals so largely look after themselves, they are so capable of finding their own food, even their own medicinal herbs, that only a minimum of direction by man is needed, whereas very considerable efforts have to be undertaken if vegetable crops are to be sown and reaped. Certainly such vegetable cultivation begins incorrectly and imperfectly with what is known as shifting cultivation. This phrase more or less explains itself. A patch of forest or bush is first cut or more usually burnt, the seed sown, reaped, the land soon becomes exhausted, is abandoned, and the community passes on, while the bush or forest is allowed gradually to resume possession of the deserted patch. Observe that in this system only half the job is done; the sowing and reaping are mastered, but the restoration of fertility to the area whose food-producing wealth has been seized by men is left to Nature alone.

Theoretically, if enough time were given, the fertility of the reaped patch would be fully restored; there can be no doubt on that point. In practice this does not always happen; we have to reckon with that deliberation or slowness of tempo which Nature chooses to impose on most of her processes of restoration. The human shift round is swift and destructive; patch after patch is burned and never fully restored; large areas become half derelict. The search for fuel to produce a more comfortable existence is often an added deleterious practice; the trees and bushes which should spring up on the abandoned patches are themselves taken for this purpose and become increasingly scarce. This situation may end very acutely, as may be seen to-day in countries like Kenya and Tanganyika, where administrative authorities have to regulate the scanty fuel supply with the utmost strictness. But shifting cultivation with its attendant evils is not confined to Eastern Africa or even to Africa; it is worldwide and still by no means uncommon. It is a most extravagant system.

The art of cultivation is not really mastered until the art of sowing and reaping in the same spot is mastered; this implies an ability *to keep that spot in such a condition that it will respond year after year;* in fact, it has to be refertilized, in other words, manured; the art of manuring is seen to govern the science and craft of agriculture. When this art has been acquired by man, he may be said at last to have started his age-long career as user of the green carpet.

We are now in a position to answer the question: what is agriculture? Agriculture is an interference with Nature; it is an interference carried on for man's advantage; it should be a restricted interference; in other words, the degree to which interference may be pushed can only be within limits which must be clearly apprehended and never overstepped if disaster is not to follow.

The very simple process of harvesting seeds, any seeds, even wild seeds, is an original interference, an intrusion into the natural cycle. For these seeds were formed by the plant for the purpose of its own procreation, and if intercepted and annexed by man all this stored energy and substance is withdrawn from its place in Nature. It does not, of course, happen that every seed of a species is taken by human agency; in wild life it could not happen, for not all seeds could ever be found, and in cultivation, enough is always reserved for the next sowing. Nevertheless, the amount of what is taken from a cultivated field greatly surpasses the amount of what is left.

On what principle does this apparently risky practice rest? It rests on the presumption that Nature can sufficiently renew herself from a very small moiety of the seed she creates. In wild life only a fraction of the seeds formed germinate, but these prove amply sufficient to carry on the species; on the same principle quite the bulk of the seeds reaped by cultivation need never be resown -- they are legitimately what we eat. We profit by that amazing system of reserves which Nature has instituted; she has far more than she needs, she has this background, this vast insurance system, from which we live. The arrangement has worked since the beginning of man's settled existence, but what is not always kept in mind is that ultimately the withdrawal of harvests must be made good by the return of wastes. Eventually, in some form, at some time, loss has to be made good by restoration; the Law of Return must be observed. Unless it is there is no true agriculture, only soil exploitation.

The temporary withdrawal of natural substances for his own consumption is thus the first of man's intrusions into Nature's round.

The second intrusion, adaptation, or modification -- whatever we call it -- is the use of fixed areas and selection of crops. Cultivation of crops connotes settlement; that is, as has already been remarked, an advance on the pastoral life. In these settled areas crops are not sown indiscriminately; a selection is made. In Western agriculture this selection is absolute -- only one kind of seed is actually sown, wheat, barley, oats, roots, or whatever it may be. (The term Western agriculture in this book must be taken to include European agriculture and also the agricultures historically derived from the European system in North and South America, South Africa, Australia, New Zealand, and other parts of the world.) The Eastern races, closer to Nature in their observation, constantly mix their grains and other crops in the same fields; even so there is a high degree of selection; there is no real approach to the confusion of vegetation which is Nature's rule, not even in Chinese horticultural practice where usually several kinds of vegetables are grown in conjunction.

This is a most important point. It is inevitable; agriculture could not be carried on otherwise. But it is and must remain a wide departure from natural law. It is so important that from the outset measures have been adopted to make good. The fallow and above all the rotation of crops are nothing but devices to restore to the soil that alternation of vegetable existences which is its birthright. But the intense degree of the demand made on the earth's fertility by this inevitable human practice of the selection and concentration of crops is not to be lost sight of; it is at the very root of our final argument to recognize it and see that it inflicts no lasting injury on us all.

In its immediate effects this departure from Nature's arrangements must be conceded as uncommonly useful. It adds enormously to the amount of harvests. Without selection and concentration of crops agriculture in the true sense could not be said to exist; the human race in its present numbers could not possibly be fed. It is the basis of the agricultural effort, and no other system can be imagined which could replace it. The only necessity is to keep it within the right limits.

Above all else it allows of the carrying out of cultivation operations. These operations are arranged to manipulate the top layers of soil and are thus designed to augment plant growth. We have already remarked on the fact that any interference with the soil itself is a somewhat violent intrusion into Nature's cycle. Undoubtedly this is so, but such operations have the support of an immense antiquity; digging, ploughing, hoeing, harrowing and so forth. All the operations which prepare the soil or cultivate it, are very ancient. Their purpose is quite simple. They aim at guiding and directing the flow both of air and of water -- those two great agencies which contribute to the life of plants -- in a way most effective and stimulating to the plant. At the same time weeds, i.e. plants other than those of the selected crop (this is the only real definition of a weed), can be eliminated. This is a subsidiary purpose; the main thing is to conduct the flow of air, which is even more cardinal than the flow of water.

Why has this peculiar, we would almost say this unnatural, method of conducting air and water to the plant to be adopted? Is it so unnatural as it seems? It is not a fair imitation of the action of certain creatures, who, in the turning of the Wheel, perform most important functions? The lowly earthworm, the ant, the termite, constitute a vast silent, million-footed, myriad-handed labour force whose aggregate effort deals with every square inch of the earth's surface in every corner of the world. Their runs and burrows aerate the soil in all directions and in the most perfect way. There will be more to say about our friend the earthworm in the course of our discussion. At the moment it suffices to point out that our soil operations, though they have the same ultimate effect as the action of these and similar creatures, are much more coarsely carried out. This can scarcely be avoided; it is not possible to conceive an agricultural implement as delicate as an earthworm's gizzard; we are bound to use stronger and therefore cruder tools. But one outstanding difference in technique must be noted at the outset; our ploughs and other instruments turn the earth up; the earthworm's action is from the surface downwards. It follows that the degree of soil disturbance effected by them is just enough to induce the circulation of the air, just enough to allow the roots of the plant to thrust themselves downwards without difficulty, and not more than this; the growing plant is not shocked or injured; whereas a number of our operations, because they turn the earth up, almost amount to excavating processes. At any rate they so seriously dislocate the surface that they are necessarily carried out at intervals between the growing of crops; only a limited number of operations can be done while a crop is in the ground.

This brings us back to our question. Why do we disturb the soil at all? Why do we not leave the whole work to the earthworm? As it is, he supplements our efforts, or, to put it more correctly, he carries out an uninterrupted continuous flow of delicate adjustments, whereas we fling in with violent and disruptive action at comparatively long intervals. The explanation is in that concentration of crops which imposes this on us. A field which is sown together is also reaped together, but the act of reaping a cultivated crop denudes a given area for. the time being of active plant life; all living growth is removed; there is a stoppage, a positive pause in the natural cycle. It is to terminate this pause, to restart the revolution of the Wheel, that we are compelled to take action, and it is quite correct to take this action by dealing with the soil first, inducing it to recommence its activity. In fact, the ancient arts of digging and ploughing are instinctive and wise recognitions of the interlocking of the life of plant and soil, of their gearing together, as we called it; in order to help the plant we deal with the soil, and that is the proper way to do it. They therefore have every justification, and, if an interference with Nature, they are so strictly in the sense in which we accepted the principle of interference -- they are the best imitation man has been able to evolve of the natural processes contributing to the growth of plants; clumsy, no doubt, by comparison with the work of natural agencies, but sensible and successful and proved by age-long experience to be so.

The first stage in the agricultural effort then is to prepare the soil and keep it in the right state, i.e. cultivate it, keep it open, as the phrase is, for the circulation of air and water. The act of reaping follows, and something will be said presently about the nature of agricultural harvests and the rewards they bring. Even then the round is not completed. After the crop is reaped, the soil has again to be made ready for the next sowing-we noted that a settled agriculture, which is the only worthwhile agriculture, implied repeated sowings and reapings *in the same spot.* That spot has to be prepared once more for receiving the seed. It must be put into such a state as to be able to supply those raw food materials which will start germination and foster plant growth.

For this purpose it must itself be fed. Once again we find the oldest practices of mankind to be an instinctive adaptation of natural processes. Nature feeds the soil by returning to it all her wastes; we have called this the Law of Return. It is universal among all races of mankind to imitate Nature by feeding the soil with waste products. The principal waste product so used is the dung and urine of animals; the addition of human nightsoil is usual, in one form or another, and has ceased only in certain parts of the world with the introduction of modern sewage systems discharging into the sea.

There is only one variation in human methods of manuring, but it is an important one. The majority of populations of the world simply accumulate the manure in a crude state; allow it to mature a little, then spread it or dig it in; the addition of seaweed or other substances is done separately. In a later chapter we shall comment on these practices. But a few nations, and among them the Chinese, who number over three hundred millions and whose civilization has lasted over four thousand years, have adopted another method. They do not normally dig in the manure crude but first mix it with some earth and abundant vegetable matter, allowing the whole mass to decay together until those processes of breaking down are fully accomplished which we defined as the hidden half of the Wheel of Life; then only is it lightly dug in or strewn over the ground. This method is called *composting*, because the end product has been composed of different and varied materials. Composting is known to other races, e.g. to our own, as is evidenced by the fact that compost is an old English word. There are allusions to composting and sometimes careful descriptions in English seventeenth and eighteenth century literature and it's clear that composting was practiced in this island; but the regular use of compost to the exclusion of crude manure is peculiar to the Chinese and possibly to a few other races .

In proportion as the nations master the art of maintaining fertility are they destined to survive; it is truly a question of conquest and survival. For in effect we are trying very hard to do something very difficult; we are trying greatly to increase, augment and intensify that part of Nature's work which seems of immediate use to ourselves. Agriculture as a true art and science goes far beyond that primitive conception of snatching at the scattered bounty which wild Nature presents to us; the reaping processes are nowadays but a small climax to long and skilful preparation. Possibly if agriculture were less skilled, less difficult, less onerous, it would not have won such a lasting place in human imagination. But even the driest economist must acknowledge it a kingly occupation; it is the first and last of professions, the one without which nothing else avails.

The ultimate aim of the agriculturist is not intrusion, interception, or intervention; it is conformity to natural law giving rise to intensification. Natural processes are to be controlled not that they may be deflected or changed but in order that they may be stimulated. Results are aimed at which shall be both richer and perhaps a little quicker than what wild life would give us. The question of the speed at which we can get natural production is not so important-there is not really much action to be taken in this direction; the annual course of the seasons is too fundamental a factor of any but the most minor manipulations and animal lives for the most part have to follow their set course with only slight acceleration at our hands. But that the reward we reap is much richer than what Nature would provide without our efforts is undoubted; the cultivated plant yields far more grain, the pruned tree larger, sweeter and more abundant fruit, the domesticated animal more milk and meat. These are the rewards of agriculture and they are of the most essential worth to man. The history of nations depends on their regularity and their continuance.

Nevertheless, as though to prove that she is mistress, Nature imposes a very marked character on what we get from her. Agricultural harvests -- under which term we include all that results from man's agricultural effort, whether directed towards tillage or towards the breeding of animals -- are quite peculiar in that while they are fixed as to the times of their accumulation, they are unfixed to their amounts. Put in a simpler language this only means -- what we all know -- that the farmer cannot alter the time of the year when he must sow or the time of the year when the crop is likely to ripen; Nature fixes these for him, and nothing but disaster follows if he attempts to defy her; for he is powerless about this, and he is equally powerless, when he does reach the moment of harvesting, about the positive amount, great or small, which he can hope to get in; for this also is settled for him by Nature.

Let us take the first point. The limits within which specified tasks have to be carried out are sometimes a little wider, sometimes narrow indeed. They tend to be most elastic in temperate climates, but these climates vary so much that not a great deal is gained that way, for very early or too late sowings are often lost and weather affects most harvests in a marked degree; indeed, the very vagaries of the weather impose a great sense of urgency about securing in time what is ready and an almost equal sense of urgency about sowing in time when the soil is warm. In tropical climates the limit of a particular sowing may be just three days and no more. In all climates the farmer may be said to be most straitly held in all he plans.

At least he knows within what laws he works; if he has the energy to do what is needed, he can conform. But when he comes to the second difficulty, the amount which he shall get, he can do nothing but wait and pray; he may reap much or little. Only one thing is certain, he cannot alter that much or little, and frequently he cannot tell until the last moment or even until after his harvesting is done, how much or how little.

The farmer is thus confronted with very peculiar working conditions. It would be unreasonable to say that he has no control over his production, but it is an uncertain control, lacking in the accurate forecasting which governs an industrial concern. By some turn in the weather or other natural circumstance his well-founded conclusions may be discounted and his reasonable calculations reversed.

If sowing and harvesting are apt to be anxious processes, marketing is even more harassing; and this again is due to natural law. Since every crop of one kind ripens at much the same moment in one locality there is bound to be set up that type of selling competition which puts the seller at the mercy of the buyer; every housewife knows how a passing glut of fruit will bring down the price within a few hours. But the problem greatly surpasses the marketing of a few plums; it is fundamental in all agricultural selling, for the reason that the production of agricultural crops is so lengthy a process that the cultivator is more or less compelled to realize some kind of profit as soon as he can; he is in urgent need of his reward. Not even the so-called mixed farm off which there is a steady flow of produce of different kinds throughout a great part of the year is really exempt from this difficulty, for in regard to each separate crop there is the usual prolonged wait and the massing of the product, and each product, it is clear, sets its own price; there is not a great deal of interchange, and if there is, it more usually has the effect of lowering a previous price than anything else, the first broad-beans lowering the price of early peas and so on.

The difficulties are increased by the fact that most agricultural produce is perishable, sometimes within a few days, and that a great deal of it is bulky and heavy to transport. Its perishable nature prevents the holding of accumulations to even out the market, though grains, even roots, tea, sugar, can be held some time, while fruits and vegetables can be pulped and canned. Conservation, storage, transport are alike expensive and the alleviations secured in these ways, if considerable, usually fall to the benefit of the wholesale buyers and not to the first producer, who has to bear the full brunt of Nature's uncertainty. It is surprising that the farmer is sometimes pushed into the position of hoping for a scarcity rather than a glut? Scarcity and glut alternate in a disastrous way in fixing agricultural prices; the first is the bugbear of the consumer, the last of the produced. A kind of unholy war develops between those who grow the food and those who eat it, and that is the root of much that is evil in our modern economy.

The nature of the agricultural reward is therefore a matter for profound reflection on the part of all who aspire to make the modern world a healthy, sane, happy world. The facts very briefly indicated are apt to give rise to pessimism; it is argued that the farmer will never be able to compete on anything like equal terms with the industrialist, for the sufficient reason that what his fields produce is so entirely different from that the factory so easily turns out; his reward is and must remain inferior. He must therefore be bolstered up, as best can be arranged, by quotas, subsidies, and other reliefs, of which it may be noted that the quota and other favourite devices rest ultimately on the scarcity principle; otherwise he must console himself with the thought of the variety, interest, and pleasure to be derived from an occupation which, on the face of it, is of a superior nature.

(An estimation of the agricultural reward in such terms of money as enables a comparison to be made with industrial rewards is very difficult; the reward of the small farmer, who makes up a bulk of almost all agricultural populations, defies analysis in money terms. An indication may, however, be sought in comparisons of agricultural wages. Adversely affected by tradition, by absence of protective legislation, it is roughly true that agricultural wage rates seldom attain much more than one half, are often only one half, and occasionally even only one third, of an average industrial wage. The statement is based on a collection of detailed facts from a number of countries made by the present author; see Howard, L. E., *Labour in Agriculture: an International Survey*, O. U. P. and Royal institute of International Affairs, 1935, pp. 204 *et sqq.*)

This view has gained some credence. It is in startling contrast to the initial thought, which springs unbidden to the mind, that agriculture is after all the first of occupations. To feed ourselves is our primary necessity and it is astounding that those who undertake the production of food should not be among the most highly rewarded members of the community. For natural plenty does exist; Nature's creation has those qualities of variety, stability and reserve which we noted in our opening chapter. There is therefore no real reason why scarcity or insecurity or unevenness of supply should worry us; nor is there any ultimate justification for an uncertainty in the reward, which should follow amply on an ample contribution to the common good.

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The Earth's Green Carpet

By Louise E. Howard

Part 2
The Application of General Principles

Chapter 4
The Retreat of the Forest

Man's disturbance of the natural cycle in the course of his cultivation is more definite that he realizes, but he continues in confidence to repeat his operations season after season because experience has taught him that his work is a success. Yet in the background of his mind lingers a question -- will the never-ceasing miracle really come about, will the seed germinate, will life be born of the dam and the sire, will there be corn, milk and meat, will the earth in truth renew her green carpet?

These doubts have led throughout the ages to innumerable rites and beliefs, particularly prominent when men are in the primitive stage of existence and still widespread and influential, even if maintained in a clandestine way, when far more advanced religions and philosophies have been evolved. Such rites and beliefs are described as fertility rites and beliefs and the concept on which they are based as the fertility cycle concept. Much investigation has been devoted to them over the last forty or fifty years and it has been proved by a mass of evidence that the central idea is that of the expected renewal of birth in plant and animal season by season; to bring this about many magical ceremonies have been and still are instituted all over the world.

That this combined hope and doubt should have been so plainly avowed among men is in itself interesting. Does it point to the fact that the yearly rebirth of the earth's green carpet is indeed an astonishing event, is, as we have already said, a miracle? To modern man the miracle is no longer a manifestation of magic; it is an established certainty, and we can up to a point explain it; we know, more exactly than primitive man could, that the first factor which brings this miracle into existence is in truth fertility, that fertility which rests in the soil.

What is a fertile soil? As we have already had occasion to state, it is nowadays the fashion for the scientist to declare that soil fertility is something which cannot be defined. The farmer would not agree with him. Perhaps it is difficult to give a precise definition in scientific language of what constitutes soil fertility, but that need not deter us from agreeing that fertility is that quality in the soil which stimulates the rebirth of life in constant and regular repetition; it is the prime rendering possible the renewal of natural things.

It is this factor of renewal which is the cardinal one.

We have already in Chapter 1 laid down the tenet that renewal is only made possible because everything that Nature creates she also absorbs again; nothing is cast aside; nothing is lost. The so-called wastes of Nature are dropped on the earth's surface and transformed into fresh forms of life; there is, as we might say, a constancy of substance. We called this the Law of Return. We also noted that this is no hand-to-mouth process, that the accumulation of material undergoing transformation after its return to the soil is immense, forming huge reserves, and that the annual or seasonal miracle springs out of these colossal margins.

Moreover, on this reserve of fertility all created things continue to draw during the course of their existence. We pictured them as jostling each other for their share of food, light, moisture and warmth. Together they form one mass of intertangled lives and functions, displaying intricacies of arrangement which constitute a dramatic illustration of natural law. The principle of mixed existences rules throughout the physical world and cannot with safety be disregarded; this, too, we are bound to bear in mind during our inquiry into the renewal of the earth's green carpet.

This principle of mixed existences embraces a great deal; it implies much of what we shall need to know. It presupposes the use of one form of created life to assist, but also to remove, another form. We may roughly call the act of assistance a living together; the scientific term for certain special manifestations of this is *symbiosis,* from the Greek, but this expressive word might be given a wider meaning. We may call the act of removal decay or fermentation or, as we shall see, we may classify it as parasitism or disease, and finally we may call it death. In this way or that, beneficently or destructively, one living thing helps, or preys on, another living thing; nothing can exist in isolation, nothing can continue separated whether from its allies or from its foes.

Of all these laws the forest is a perfect example. It exhibits continuous and permanent fertility; it is the pre-eminent portion of the green carpet to which are assigned the living reserves of Nature; it is a marvelous example of mixed existences. The forest is composed, in the first place, of one of the most lovely creations we know, of trees. But it is not composed of trees alone, though we are apt to think of it in these terms. First, it includes a remarkable variety of vegetable growths other than trees, which in a wild forest are always of different kinds. There are to be found in the forest abundant mosses and lichens, annual and perennial plants and flowers, shrubs and bushes, and usually creepers and lianas; in tropical forests lianas with orchids occur in profusion and form a special cover or network, so thick as to constitute a well-defined layer at the top of the tree stems near the light, inhabited by a specialized fauna living in a high world of their own -- a very remarkable fragment of the green carpet. Further, there exists in all forests, temperate or tropical, a mass of fungous growth, which seems essential to the continuance of the trees; indeed, an intimate and necessary connection has lately been proved between the growth of certain tree species and their associate root fungi.

These varied forms of vegetable life are not the end of the matter. The forest is also the home of a vast animal population, far larger than is generally estimated. There are the birds. There are a number of larger mammals, and the fact that our convenience and safety has eliminated these in civilized countries must not tempt us to forget them. There is always a very large population of smaller animals, rodents, snakes, lizards, etc. There are worms and invertebrates generally; finally, there are masses of insects, both those which can reach the air by flight and those found in the soil. Finally, there are microscopic types of animal existence in myriads.

Thus the forest is a combination of forms of life whose character it is to be interlocked and mutually dependent; the finest piece of invented machinery could never rival the delicate and vital adjustments which constitute a forest system.

It is the special nature of trees to form a truly magnificent protective cover to this complex creation. Under their canopy this mixed world goes on undisturbed and richly. The result is that accumulation of reserves, that stored fertility which is the very sign manual of a forest.

Generally speaking we may say that the solid portion of the earth's surface is divided between forest and grass; we may omit rocks and desert. These two forms of the green carpet are alternate and their respective advance and retreat depend on circumstances, climatic and geological. In moist climates on the whole the trees win, especially in the temperate zones; they are what is known as the ultimate succession; in other words, were Nature left to herself she would at once proceed to cover most of these zones, first with scrub, and then with a thick forest -- the process may be watched at its start in any neglected field when the hedges begin to grow out into uncared-for pastures. Yet we know that within the period of our existence the reverse process has taken place -- the grass has won on the trees. The retreat of the forest has been the result of man's wish to cultivate, and has been a major event in the history of the human race.

It has come about gradually. In some parts of the world it is still going on, in others it took place centuries ago. In England, as long as population was scanty, the cultivation of the higher and drier downlands sufficed, but with the increase of its population consequent on the Anglo-Saxon settlement the valley forests were destroyed to make room for fields. The continent of Europe had been subjected to the same process some time previously; the Mediterranean forests perished some considerable period before the birth of Christ, the Northern European forests lasted until the Roman Empire or later. But Europe has not been the sole example of these acts of deforestation. Both the Americas, much of Africa, parts of Central Asia, parts of Australia, almost the whole of New Zealand used to exhibit thick forests, all now destroyed or being destroyed by man.

What have been the consequences? Much of this destruction including a great deal of what is happening at the present day, has been wanton; it is inflicting great injury; it should be stopped. It is not, however, our purpose to dwell on this aspect. Let us rather look at the question in a larger way.

Man is bound to eliminate the forest. He must have fields for he must grow food. But in laying out the earth into tilled and cultivated areas he should grasp what he is doing and set himself with deliberation and with firmness to make good his interference in the natural order. If he is obliged to disturb the earth's green carpet, he should assist Nature to reconsiitute in other forms what he disturbs. He cuts down a tree, a group of trees: well and good; but let him learn of the tree, let him study all the tree can do.

The role of trees in Nature is a very important one. We will take what they do point by point, and base the remainder of this chapter on a consideration of three separate functions which they fulfill. These three functions are as follows:

In the first place, they anchor the soil. This mechanism -- for so it may be called -- is particularly observable wherever there is a slope, for it is here, of course, that the soil tends to slip out of place. But it is effective everywhere. Moreover, the tree stems, together with the leaf canopy, simultaneously protect the top layers of the soil from the effects both of sun and of wind -- the latter far more deadly than might be realizedand also break up the rain into a fine and gentle spray. In the forest the rain drops very quietly on the soil and the wind is broken. The result is that the top layers of forest soil remain not merely anchored in their place but absolutely undisturbed. That is why they are able to remain extremely loose and that again is why they are so beautifully full of air.

Nothing like this is to be found elsewhere. The carpet of grasses and other plants which is Nature's alternative to the forest is much closer and more likely in course of time to cut off the air from the soil; as the roots decay they may form an almost impenetrable mat. It is true that these roots hold the soil securely in place -- it cannot be blown or washed away or burnt by the sun. But the forest alone combines the two functions of affording a completely adequate protection and of yet allowing entire accessibility to the air. The floor of the forest remains therefore as the most perfect illustration of natural soil build-up; the constructional method employed is, so to say, exemplary.

The topsoil of a forest -- the product of tree growth -- is a wonderful thing to examine and will repay almost any amount of investigation; its delicious smell is most attractive to the senses, its lessons are infinite to the mind. But the beneficent action of trees does not stop with the topsoil. The roots of almost all trees go a considerable way down and those of some trees penetrate to a surprising depth. Here they meet the subsoil and often touch the parent rock.

What are their functions in relation to the subsoil? Before answering this question we need to know a little about this subsoil. There are two main points to realize. First, the subsoil, like the topsoil, has a life of its own; second, the life of the topsoil is in intimate relation with this life of the subsoil. Just as the plant is geared to the topsoil, so is the topsoil itself geared to the subsoil. The process goes further. The subsoil itself is geared to the parent rock on which it rests. (Clay and chalk are included in the expression "parent rock".) In fact, each layer is derived from the preceding-the topsoil from the subsoil, the subsoil from the parent rock. There are continuous processes going on by weathering, pressure, upheaval, leaching and chemical action which bring about a constant formation of fresh soil upwards and downwards. The earth's crust is a piled series of such layers (technically known as horizons; the whole set of horizons looked at in vertical sections is called a soil profile), often broken and bent into confusion or otherwise mingled by alluvial deposit, gravity, friction, wind, etc. Nor is this a finished process. It is still going on. There is a geological life proceeding with vigour right under our feet though we do not often become conscious of it.

It is the roots of trees which provide the mechanism required to bring the various soil strata into relation with each other. They shatter the soil in all directions. They provide innumerable channels down which the rain can creep. As they decay they leave positive vents which draw in the atmosphere; aeration follows drainage. It is the combined effect of the passage of water and air which starts up the life of the soil. Without these two elements that life would soon die down; the weathering and leaching processes would cease, the subsoil would be unable to form, as it now does, ever-fresh layers of topsoil; it would not itself be constituted from the parent rock. The effects would be disastrous. There would be completely static conditions. Drainage and aeration are necessary to the life of the soil, which is as sensitive to their cessation as any living being.

But trees have yet a third function besides those, first of anchoring and then of draining and aerating the soil. This third function is a fertilizing one. It is the business of trees to pull the minerals out of the lower layers of the earth. For the store of minerals needed for proper vegetable growth, and eventually for proper animal growth, are banked in the subsoil into which they have passed by slow disintegration from the parent rock. Banked at this level they would, and do in fact, stay there unless sucked up by the pumping action of tree roots. The roots of trees penetrating many feet downwards are the most effective agencies which can perform this necessary task. If the pumping action is unhindered these minerals pass into the true structure and foliage. In due course they leave the tree in the form of the autumn leaf-fall, and in this way they are finally distributed over the surface of the earth. If the pumping action fails, plants and animals have to go short of minerals. The roots of trees are therefore a vital connecting link between the members of the natural round; they are Nature's great circulatory system, and to eliminate them is like removing the veins from a man's body.

For the forest manures itself; it is there that the fertility cycle is most intense. Nothing quite equals the lay-out of the forest. Whether we look at the perfection of its mechanical action in securing the soil in place or at the completeness of the drainage and aeration systems which it provides or at the effectiveness of its manurial renewals, we see something which surpasses any other manifestation of the green carpet. Time and again we can go back to the forest and study it afresh.

We are now in a position to consider what consequences are likely to arise when in our constant search for the areas in which to grow food we cause the forest to retreat. We may sum up our conclusions under the following heads:

There is, first, the obvious effect of loosening the soil. When no longer held by the roots of trees the top layers of earth are easily removed by wind or water through the natural process known as denudation. This continues until the actual configuration of the landscape is altered. In its acute forms denudation becomes erosion, when deep rifts and gullies appear which widen, or the soil of a whole hillside is gradually shifted and carried away. In the second place, there is the interference with the natural drainage and ventilation of the soil which follows on the large-scale removal of trees. The farmer has always sought to make good any harm he has done in this direction. Up to a point his efforts have been successful, but there are dangers here also, as we shall see. In the third place, in replacing forests by fields we have not merely interfered with, but have definitely put out of action the natural circulation of minerals. On this point traditional agriculture has had no certain knowledge, and the farmer has had little to guide him beyond his instinct and feeling for the land.

Let us take these three points one by one. So much has been written about the incidence and effects of erosion that it is not necessary to repeat what is well known. These effects are worst in countries of climatic extremes. Here the damage is rapid and apparently irreparable. The fertile landscape vanishes; the country takes on a bare and hopeless look; stretches of sand lie everywhere and rise in clouds of dust with the pitiless wind or are washed down into dangerous sandbanks by illregulated and torrential streams; the rich vegetation fails to reappear, a few hardy species struggle on; gradually even these may vanish. Invasion by the desert has begun.

Elsewhere the effects may be less pronounced. We may notice here or there a gully or a field of which the topsoil has been washed down to the lower levels with detriment to the crop-growing capacity of the higher land; or after a strong wind in open country we may see topsoil blown away together with the sprouting crop; this now takes place in a few districts over our own country and has caused much alarm. But even if erosion so far plays a very small part at home, we must confess in looking over the world as a whole that it has a long and sinister history. No part of our earth is unvisited by this evil. In Europe any traveller in northern Italy will mark the deep, scooped-out depressions interrupting the contours of this most highly cultivated land. The south of France, Greece, Palestine have not suffered less -- all these countries share the evil, while on the other side of the Mediterranean North Africa has partly collapsed in desert, a desert which advances at the rate of two-thirds of a mile a year; indeed the Mediterranean basin is the classic example of the erosion following prolonged human settlement.

In other countries there are plenty of examples. In the Orange Free States useless gullies replace what in 1879 was an area of rich grass interspersed with reedy pools. In Ceylon, where the tea gardens have been formed on bare slopes stripped of the original jungle, erosion has carried away millions of tons of fruitful soil. In China, where thousands of miles of the higher stretches of the great rivers have been completely denuded of trees in the persistent search for fuel on the part of the peoples living at those levels, the soil, deprived of its natural anchorage, collects as a vast mass of suspended matter in the river streams, gets deposited along the lower courses of these rivers until the river bed is so raised that the waters spill over on to the flat fields on either side in the form of devastating floods; it is estimated that every year two thousand million tons of soil, sufficient to raise an area of four hundred square miles by five feet, are carried down by the Yellow River alone. Both in this country of China -- otherwise so far-seeing in its agricultural technique -- and in the United States of America along the course of the huge Mississippi River and its tributaries, the short-sighted remedy is adopted of trying to keep the river in its course by building mud banks -- levees -- on each side. The river merely rises higher and higher and always ends as the victor, for the human effort fails before the immense force of the waters with their burden of suspended matter. Terrible as is the effect of this water-borne erosion, it is equalled by the wind-borne destruction of the prairie plains of North America, which has carried away in dust storms thousands of dried-out acres of farming land; whole areas have been reduced to the condition known as dust-bowls. These are only a few of the best-known instances of a destructive process which seems to be increasing in its extent and its intensity.

Nevertheless we should not lose sight of the fact that denudation in the form of interchange of soil is normal in Nature. Our lands have been formed by the weathering of rocks and the washing-down of the results; it is one of the positive duties of streams and rivers to transport particles of soil. It is when the process of denudation is exaggerated that we begin to be alarmed. We despair of what we may have done in our centuries of human history; we wonder whether the human race is destined to work nothing but injury on the earth which it inhabits.

We need not be alarmed. Nature does not forbid us to open up the earth. She does not insist on the forest everywhere and at all times. If that were so, we should have to grow our crops as best we could under a forest canopy. It is true that some agricultures have gone much too far in the elimination of trees; but nothing absolute is imposed on us, nor indeed has Nature imposed it on herself. As we have already remarked, the prairie and the steppe exist side by side with the forest and also hold stores of fertility and great marginal reserves.

This may provide us with the secret of what we have to do. If the renewal of life is to take place, if the green carpet is not to be rolled up forever, then there must be no lengthy interruption in verdure -- nor does Nature admit of it herself. Bogs, marshes may form; growth and change may decline to a minimum; but some sort of green cover is always there, if not the forest then the savannah, the prairie or steppe, if not the steppe, the marsh or bog. Once all these are removed we have a desert, and though a desert is not usually entirely without life, it still seems to. remain as an almost ineradicable scar on the face of our earth. If Nature is able to restore deserts, she does so but slowly; most deserts seem permanent, terrible proofs of the need for continuity in the green carpet and of the void which follows on its lapse. In truth deserts are not a normal illustration of Nature's working methods. She prefers her green carpet and exerts all her power towards its maintenance.

The best check on erosion, therefore, is the growing crop. This is the real preventative and also the remedy. One nation, the Japanese, has found it so. Japan is a country where the steep configuration of mountains and valleys, combined with the climatic condition of heavy seasonal rainfall, lends itself peculiarly to the evil of erosion; yet erosion is successfully combated by the Japanese agricultural engineers. Each river system is studied as a whole, and following on that study, dams are gradually built in the upper valleys, with careful observation of results. Sedimentation, and above all, natural revegetation are allowed to run their course. In fact, the Japanese engineer applies to Nature to help him; he confines himself to encouraging the re-establishment of the wild forest; the re-established forest then absorbs the rainfall, the streams cease to be agents of destruction, the precious paddy fields in the lower valleys remain open and unharmed. Thus cultivation areas are secured on condition of leaving the upper slopes to Nature's persistent habit of replacing the tree where it is needed. The areas secured for human use are small -- the areas left to Nature's domination very large; but the Japanese engineer is wise; he knows the folly of attempting more. His reward is that what he has he holds.

If Nature is properly approached she can do even more for us; she will be quite willing to put back what she has taken away even of cultivable areas. This was proved in Gwalior in India, where the simple construction of embankments with spillways in a very short space of time resulted in the formation of fine wheat-bearing areas where there had only been useless eroded land. Erosion, therefore, is by no means the hopeless problem which it is so often supposed to be. The very power of the forces which originate it can also be used to make it good.

Yet it scarcely admits of argument that prevention is the aim. Terracing on erodible lands should never be omitted. Primitive agricultures are exemplary on this point; for it is life and death to the people living by them. Modern plantation agriculture has been terribly neglectful; the classic examples are the plantation areas of Ceylon, which contrast most unfavourably with the island of Java where the Dutch have taken the severest measures to insist on ample terracing. In general, the great rice areas of the East are most marvelously terraced by peoples who have had only their hands and a few tools and animals to help them.

Slowly the Western people are also beginning to correct their past mistakes. A new device is contour-ploughing, i.e. ploughing across a slope and not down it. This is like a miniature form of terracing, especially when each fifth or tenth furrow is ploughed deeper. The furrows act as small channels to collect the rain water, which soaks in gently instead of washing down the slope carrying the mud with it. Or again there is strip cultivation, which means the sowing of two different crops in alternate strips. These two crops grow and are reaped at different times, so that the crop left acts as a protection to the exposed strips; the force of the sun, the rain and especially of the wind is broken; this is a partial but insufficient application of the principle that the earth should not be completely bared of her green carpet. Contour-ploughing and strip cultivation have been found useful in the United States of America and in South Africa and have done a good deal to begin the check on erosion.

The retreat of the forest then can so far be made good; where necessary the forest itself can be re-established over a part of the catchment area or' such configuration on a large or small scale can be put in hand as checks soil loss. Thereafter all is well provided, that the green carpet is maintained, and that *nothing else is done to destroy the nature of the soil.*

For not even the best contoured and protected field will stand up against the eroding force of sun, wind and rain -- those fierce agents to whom is assigned the great task of reshaping the earth's form and surface -- if its most intimate inner structure is irretrievably damaged. The soil itself must be respected; the soil structure must be retained in its integrity. As well expect our bodies to prosper after all our corpuscles had been blown apart as expect the earth to remain kindly after her beautifully composed structure has been broken down into and dust. .

This truth is appreciated by all farmers. They are experts, trained by centuries of experience, in the feel of the land. They know by the tread, by a rub between the hand, by the resistance of fork or spade, by the draw of the plough or harrow what their soil is like. Is it crumbly? Is it sticky? Is it powdery and poor? The exact condition is apparent to all who have mastered the art of cultivation. They know that a good tilth is everything.

This good tilth depends on retaining the compound soil particle, which, comparatively large, provides shapes of irregular contour and plenty of air space constituting substance and resistance. The effect is, in the first place, physical and depends on laws of mechanics; fine particles would pack close and be impervious; big particles lie loose and *cohere;* they, so to say, hook into each other. But if the effect appears to be mechanical the cause is something different. The compound soil particle, the particle which, once for all, prevents a complete process of erosion which holds its own against the action of water, sun and wind, which makes possible crop cultivation on the open level and even on the more dangerous slope, is the same in the field, steppe and prairie as on the floor of the forest. It is glued together out of minute fragments of mineral matter by means of a pastry cement supplied mostly by the dead bodies of the soil bacteria. It is when this compound soil particle disintegrates that the soil becomes dust and as such forms the prey of water, gravity and wind. The maintenance of the compound soil particle is therefore what matters, and if this depends on an adequate supply of the pasty glue or jelly referred to, then there must be plenty of the specks of dead microbial matter to make it; in other words, there must be a rich microbial population in any soil which is to hold together. Now the microbial population lives and dies -- we are in the midst of a biological phase. In truth, we have left any mechanical safety devices far behind and have entered into the life of the soil.

This is the gist of the matter. What we know as soil is a changing dynamic complex of living and dying organisms mixed with inert mineral matter and with decaying vegetable or animal wastes, the different constituents being brought into relation with each other in a very remarkable and varied way. But none of this is possible unless the teeming organisms which conduct the life of the soil have plenty of the organic wastes on which to feed. These wastes are their food supply; cut off this food supply and they cease to exist.

Thus we come back to the Law of Return, the essential pre-condition of soil fertility. It is on fertility that the preservation of all soils depends; the problem of erosion is a problem of fertility. This is why in considering the retreat of the forest it is a mistake to lay too much stress on the anchoring action of the tree roots; this anchoring action can be to a large extent forgone -- as we see in our fields -- provided that the fertility natural to the forest floor is not also sacrificed.

We now come to the second of the three consequences which we noticed as arising out of man's interference w ith the growth of trees; we stated that in eliminating trees he destroyed the natural drainage and ventilation which they secured for the soil. As in the matter of the anchorage of the soil in place, this is so obvious that the cultivator has from time immemorial kept the problem in mind. Our ordinary agricultural operations, the antiquity of which has often been remarked upon, rest upon the necessity of doing all that is possible to assist the entry and dispersion both of moisture and air into the soil. Ploughing, harrowing, digging and hoeing are all conducive to the great task of making water and air available where they are required, i.e. where the roots of the plants can use them. To these annual or seasonal operations are added from time to time important efforts designed to secure the same conditions. The lay-out and shaping of fields, but above all their drainage by whatever system, whether by ditches or pipes or sloping, is considered an essential part of the art of cultivation; or there is irrigation to be undertaken, which is an operation requiring the utmost skill and understanding. All these efforts are really one great effort; they all aim at the introduction of air and water at those levels where the roots of our food-bearing crops are sure to look for these two agents to their growth.

In these operations we greatly miss the help of the tree roots. As we have already noted, these roots are unrivalled conductors of air and water. Our habit of substituting something else for their action carries us on for prolonged periods, but ultimate conditions sometimes accumulate which are elusive and baffling and which call for a certain reconsideration of agricultural practice.

One common condition is the formation of what is known as a pan just above the subsoil. A pan is a stratum or layer of closely packed soil which has caked and hardened; even though originally only sand, it may become as impervious as a shelf of stone. (Anyone can observe the process by watching what happens in a jar of sugar left for some time. The fine grains conglomerate into a mass, which if left for long can become quite hard. Sand packs even closer than this and therefore becomes impermeable.) A pan may be close to the surface or some way down. Wherever it is, it is very injurious. The passage both of air and water downwards is impeded, if not entirely cut off. This spells death to the crop. A plant must breathe downwards as well as upwards. It must grow downwards as well as upwards, but only a few hardy plants have the force to shatter the stony opposition of the pan. Most plants find their roots checked and mutilated; is it surprising that they suffer? A peculiar stunted growth above ground is the surest sign of this mutilation below. Wherever the farmer or gardener finds his crops in this state he should at once probe for a pan. And it should be noted that pans may occur almost anywhere, in a suburban garden, for instance, where the builders' gear in constructing the house has pressed heavily or where the lorries have drawn up, even if only for a few weeks.

There is every reason to suppose that the soils of our own country are suffering from the formation of pans. Centuries of the passage of men, animals and machines have had the result of packing and pressing the soil. The invention of large and heavy machines like tractors must have hastened the process. There has been prolonged washing-down of finer particles to lower levels, where they accumulate and choke the soil air spaces. Cultivation has kept the topsoils open, but this has only helped to conceal what has gone on below these. An examination of our subsoils would probably reveal a surprising state of affairs.

A pan is not difficult to deal with. There is a new practice, known as subsoiling, which consists in drawing, by means of a tractor, a sharp thin wedge through the subsoil, which is thereby shattered. Aeration and drainage are at once restored. The effects are quite remarkable. They surpass what has hitherto been accompanied by dressings of basic slag, dressings which are really no longer necessary in view of the new technique of subsoiling.

(Subsoiling was experimentally carried out by the late Sir Bernard Greenwell at Marden Park, Surrey, in 1938 with highly successful results; for details see Howard: *The Soil and Health -- Farming and Gardening for Health or Disease,* pp. 199 *et sqq.* Dressings of basic slag [which means the used-up lining of the Bessemer converter] were first introduced about fifty years ago. The usual explanation has been that the phosphorus content, removed from the iron ore, acts as a chemical fertilizer on pastures; the more likely explanation is that the effect has been a purely physical one, of aeration; if this is so, subsoiling is a better and cheaper method. For the superior effects of subsoiling over basic slag dressings see communication by Mr. Delgado of Little Oreham, based on observations, on two treated fields in 1943-4, in the reference given above. Basic slag permanently kills the edible mushroom, but apparently not on all soils.)

But an even better remedy presents itself. Once more we can ask Nature to help us. We need not be fearful of causing the forest to retreat provided that we follow rather more closely than we sometimes do, what she institutes when she herself chooses to alternate her forest with grass. Her arrangements in these areas are not dissimilar from her arrangements in the forest. With marked differentiation of growth the various grasses and meadow plants lift themselves so as to use every inch of the light -- some are tall-stemmed, some short-stemmed, some creeping. Exactly the same rule is followed below the surface, some plant roots thrust deep, some are shallow-rooted, some creep just below or even above ground; thus, down to a depth of three, four, five or six feet every inch of the soil is combed and divided. Here we have the same pattern as in the forest, where both above and below the soil every possibility is sought out. Thus what the forest does on a grand scale is also done by the prairie and meadow in a smaller but no less effective way.

How very thorough, how very useful and indispensable this combing and shattering action of the smaller plants can be is what we ought not to forget. There has been a certain tendency to do so in our own country -- the improvement of our grass mixtures has run in the direction of concentrating on the rich shallow-rooted grasses. The Eastern cultivator has been cleverer; he consistently uses deep-rooting plants like the pigeon pea in his rotations; these he considers indispensible. What a weapon we also might have, what a sure preventive of evils like the soil pan, in our own burnet, chicory and cocksfoot! Fifty years ago a far-seeing reformer described these plants as "the cheapest, deepest and best tillers, drainers and warmers of the soil". From his own experience he gave a truly remarkable picture of what they can do. About fourteen inches below the surface of one of his fields he found a pan ten inches to a foot in thickness so hard that a powerful man with a sharp spade had to use great force to break it open; this pan had been formed by the washing-down from the topsoil of very hard minute particles which by reason of their smallness had arrested capillary attraction; in fact, it was a compacted stony mass without compound particles or the air spaces which these create. Yet close set as was this pan -- the expression he uses is "apparently impenetrable" -- the roots of chicory had passed straight through it without deflections and *had succeeded in disintegrating it*; their roots had pierced to a depth of thirty inches, the roots of burnet and kidney vetch to twenty inches, and of lucerne eight to ten inches. In general, the plant roots "seemed to have a profound contempt" for the pan. (R.H. Elliot: *The Clifton Park System of Farming*, ed. Faber & Faber, p. 98.)

This is the help we should use if we wish to make good our interference with natural forest growth. If for valid reasons we feel ourselves compelled largely to eliminate one of the constituents of the green carpet -- the tree -- we have only to turn to another type of constituent, and our difficulties are solved.

Let us first understand Nature, and then be as bold in our practice as we please: understanding is the first and only step to right action.

But is this all we have to apprehend? Do the ultimate consequences of the retreat of the forest stop at the two effects of loosening the soil from its natural anchorage and allowing it to pack? These two effects, though at first sight a little contradictory, clearly arise out of the same cause, namely, the removal of the tree roots. They are mechanical effects having biological consequences. Do the results of the retreat of the forest end here?

The essential role of the tree in Nature is not only to be a mechanical agent whether for anchoring or for shattering the soil, it is also destined to act as the perfect chemist, analyst and distributor of mineral riches. It is not only the roots which perform this function, but the whole tree system contributes, for the minerals absorbed by the roots from great depths pass up the trunk into branches and leaves and drop as the leaf-fall; in this way they reach the surface of the ground and enrich the topsoil, where they are available for plant growth. This we have already stated. The tree therefore serves not only itself but the whole vegetable kingdom in thus pulling up the mineral wealth of the subsoil.

(There is another agency which also distributes the necessary minerals: water. Glacier water is especially rich. Very notable examples of magnificent cultivations fed by glacier water are to be found in places as far apart as the Hunza valley in the Gilgit district of the Himalayas and the La Crau meadows in Southern France; the hay from these meadows is eagerly sought by distant trainers of racehorses; it gives great stamina, a result doubtless of its perfectly mineralized condition; the stamina of the tribesmen of the Hunza valley is by now proverbial. Other examples of cultivation enriched by glacier water could be found, especially in Switzerland. Mud-laden waters also are full of minerals. This mud carried from the higher reaches of the river is soil which has at one time or another been well supplied with minerals. Spread on the fields, it keeps the mineral content at a good or even a notable level. That is why the Chinese practice of spreading canal and river mud is so important. In Egypt the mud is spread by the river itself; and the effects have been adequate for many thousands of years.)

It may be well imagined that this last function of the tree in Nature cannot be disregarded without dire peril. A reasonable number of trees are a necessity in any permanent system of farming. Such, for instance, are the shade trees commonly found in the best tea gardens: these trees do a great deal more than merely provide shade; there are always palm trees in an Eastern rice field. In general, there is a great distinction to be drawn between agricultures which are treeless, such as those of the South African veldt, and agricultures which maintain a real residuum of tree growth, such as the European and the Asiatic.

In nothing has British farming shown itself so sensible as in its retention of the hedgerow. A hedgerow is really a small strip of surface-drained forest left in position. It has been noticed that the grazing animals are very fond of the herbage next to the hedges round their fields. The explanation given is that they here find the wild herbs which may have been omitted from the new pure seed mixtures with which their improved pastures have been sown, herbs necessary to their diet, grown, moreover , in the rich humus-filled and drained soil which collects under an English hedgerow. But perhaps this is not the whole explanation. Do they also find in the vegetation near the trees, of which there are usually a few in our hedges, and in that under the larger bushes supplies of minerals and does instinct cause them to crop these plants by preference? If this is so, we have quite a good contribution to the science of animal husbandry and quite a reasonable additional explanation of why animal breeding so excels in England, where for many years past the tree growth has been generously replanted along our roads, avenues, hedgerows and in our parks, fields and gardens.

Here is the explanation of, and the remedy for, those deficiencies in trace minerals of which so much has lately been written. Trace minerals -- manganese, boron, cobalt, etc. -- are so called because only the veriest traces usually exist in the soil; nevertheless, the absence of these minute quantities is very injurious to the health of all animals, including ourselves. The somewhat limited investigations in this field have left the subject there; the advice given to the farmer not going beyond the idea of establishing a deficiency and re-adding each mineral separately to the soil as indicated. But none of these laborious investigations and re-additions recognizes the fundamental fact that where trees have been too definitely eliminated, the soil will sooner or later deteriorate, and that the only way to deal with the situation is to restore tree growth in whole or in part.

Assuming then that we shall maintain at any rate some trees and if possible some hedgerows, can we now dismiss this subject of minerals? Not entirely. There is one element, the loss of which is almost sure to cause us anxiety; this is calcium. (Calcium is denoted by the formula Ca. Limestone = calcium carbonate, $CaC03$; quicklime, which is obtained by burning limestone = calcium oxide, CaO; when slaked, this becomes calcium hydrate, $Ca(OH)2$.)

Calcium, the element to which the farmer is referring when he talks of the necessity of lime for his land, exists in various forms. These range from limestone rock to layers of chalk. Although inorganic it is perhaps worth noting that they have had an organic origin, for they are the residue of millions of shells and skeletal structures of minute marine animals once deposited on the floor of the ocean. In the course of ages these deposits have emerged to form part of the earth's dry crust. This limestone is therefore a natural soil constituent. It is invariably found in an impure state and is present in unequal quantities in different soils; some parent rocks contain little limestone, which means that the subsoil and topsoil will also be deficient. It is, moreover, exceedingly soluble. Dissolved in the slightly acid soil water which percolates downwards in our climates, it quickly leaches away out of reach of the plant roots.

The limestone content of a soil and its accessibility are of great importance in the cultivation of crops. The crops we grow need the calcium carbonate of which the limestone is composed. Not quite all of them-tea is an exception; still, the majority of cultivated crops must have limestone. Not only is this substance a raw material needed by the plant, but it has the invaluable property of making active other soil materials. Without limestone these materials become, so to say, locked up. They are there, but the plant roots cannot use them; crushed limestone sets them free for the plant. Further, certain soil bacteria must have this substance; they are unable to operate in a sour soil. In a limestone-starved sour soil neither bacteria nor plants can use the food materials which are there; we might call this almost a breakdown in the manurial cycle or at least a very great slowing down of the machinery.

This does not suit us. We want to intensify, not to slow down. We are really facing a double or treble difficulty. Our cultivation practices, especially our practice of increasing drainage, greatly add to the tendency of the soil to lose its calcium carbonate by leaching; meanwhile our intensification of growth is making extra demands on this reserve: but simultaneously, by cutting down the forest, we are removing the one agency which can pull it up again. We may add that by depriving the soil of the foliage canopy of the forest we permit the rain to fall with much greater force on to the surface of the earth; this undoubtedly increases its leaching action; a great deal of the leaching effect is to be attributed to this cause. In truth, the retreat of the forest is at the bottom of the whole business; the calcium deficiency in the soils of Europe has arisen because we have interfered with the natural circulation of this element via the tree roots and tree foliage; according to Darwin the dying leaf continues to collect calcium almost to the end, so that the leaf-fall is particularly rich in this substance. It was part of the wisdom of the European peasant to have realized the situation and to have sought a remedy. The practice of liming the land is very old, how old we are not sure, but it is mentioned in Pliny. As it was originally impossible to crush the natural limestone by human labour the easiest practice was to burn it, then slake the quicklime so produced and thus make a product easy to scatter, the remains of old kilns may be seen almost everywhere in our country. It is now, of course, possible to crush the natural limestone or chalk -- a signal instance where the invention of machinery has been of great use to agriculture; the process of burning and slaking are no longer required. Modern transport puts such material at the disposal of every farmer. Nevertheless the universal use of this substance is in itself a confession that our soils have forfeited some of their original quality, that they have lost something, that they are not the same as when Nature first put them into our hands.

The Eastern races do not have recourse to liming. The Indian peasant does not dream of putting slaked lime on his land. The Chinese peasant, though he knows of lime for building purposes, does not use it in his agriculture. It is true that some of the alluvial soils of the tropics are not so subject to leaching as our own. The effect of six or eight weeks of heavy precipitation is nothing like so intense in washing out lime as the continual moisture that falls in temperate zones. But the real reason is not this. The Eastern peasant has learnt the secret of keeping his soils absolutely fertile. He guards himself against any soil. exhaustion with the greatest care: he always uses a deep-rooting crop or trees in his rotation. A really fertile well-managed soil will be sure to contain lime -- the difficulty does not then arise. Shortage of lime comes from short-term policies in farming, in fact, from bad farming. It will be interesting to see how far the lime shortage of Western agriculture can be cured if all natural wastes without exception, including above all such wastes as leaf-fall and twig-fall, are restored to the land. It will be a very long process, for the loss of lime is a very old injury inflicted on the soil. (As calcium carbonate is a natural mineral constituent of the soil it cannot be classed as an artificial manure; the addition, or rather the restitution of lime to a soil is something quite different from the use of artificials; we are simply trying to restore the soil to a certain natural state. Dressings are best added to the compost heap, where they help the work of the bacteria.)

We must at length sum up our analysis. The retreat of the forest is inevitable; it is the condition for human advance. But there is a wide difference between the blind destruction of what is the richest manifestation of the earth's green carpet and a wise and patient cultivation which slowly lays out the fields as they should be laid down, leaves a sufficient growth of trees and so far follows natural principles as to insure that the anchoring, draining, ventilating, and fertilizing action of the trees is continued and maintained by appropriate means. That these means must vary from place to place and even over different periods in our history may be granted. But two devices may recommend themselves to all.

Wherever we go we should leave or should reconstitute a few acres left wholly to Nature, such as portions of an original jungle or national park. Here Nature will maintain or will replace what is most suitable to the climate and the soil; she will arrange her successions as she pleases. From her action we have everything to learn. Time and again we shall be able to study what she does afresh. For Nature, undirected, can direct us. Every extension of the areas of human cultivation should therefore pay attention to this precaution. More especially should the great plantation industries, in opening up virgin regions, be most careful to leave undisturbed some tracts, not too small, of original jungle or forest; these will then serve as control areas to which reference can at all times be made. Such a practice will stand the farmer in good stead and will be of the greatest assistance to the scientist.

In the second place, we should not hesitate to make a larger sacrifice. It is probable that in the long run nothing can completely restore soil fertility except the replacement of forest growth. The forest is such a unique piece of natural machinery for starting up the manurial round that nothing can ever be entirely substituted for it. It would be the highest policy at definite intervals to replant portions of our food-growing areas with trees until they shall have regained that natural status which is the beginning of all wealth. After a sufficient period we could take them into use again. As they are felled, important additions to our timber supply would accrue. The forest, in fact, would be a long-term rotation crop.

This would entail some sacrifice. Only a public authority could embark on a programme which must look forward to the benefit of future generations at cost to the present. It is therefore not easy to introduce or advocate this far-reaching principle. Yet it would be the wisest of all plans, because it would reconstitute the natural sequence which cultivation by man, of its very nature, cannot help injuring. Unless we are prepared to embark on some such fundamental corrective of the errors which have crept into our soil management in the course of centuries, we shall always be plagued with the evils which are bound to follow the slow dwindling of soil fertility consequent on the retreat of the forest.

Man, as we have stated more than once, can and must interfere with Nature if he is to exist to any purpose: but how infinitely small is the degree of his interference when contrasted with the vastness of the obedience he has to render! To lay stress on the interference and to lose sight of the obedience is folly indeed and very bitter are the fruits thereof.

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The Earth's Green Carpet

By Louise E. Howard

Chapter 5
The Animal as our Farming Partner

The forest system includes the animal kingdom. We pointed out in our last chapter how rich and diversified is the animal population which pursues its life history under the forest canopy. We can now expand this statement and note without further parley that what is true of the forest is true of the prairie, the steppe and meadow, even of the bog and marsh and desert; animal life abounds; animals are a part of the natural order so essential that no portion of the earth's green carpet can exist without them. Indeed, the relationship between the animal and plant is the most significant of any in Nature. Animals and plants lead an interlocked existence: the connection could not be closer, more permanent, and more crucial.

We have no true conception of the green carpet unless we look on it as a double world of animals and plants together. This is natural law and it is our business to draw the right deductions; if the co-operation of animal and plant is the basis of the life of the forest and the prairie, it should also be the first principle of husbandry.

There are three ways in which the animal becomes our farming partner. It provides us with end products, such as milk, wool, meat, horn and hide; it provides us with power for pulling and drawing our implements; it provides us with dung and urine to enrich our fields. Many systems of farming use the animal for all three purposes together. When farming becomes wealthier it is usual to distinguish between the beast kept for man's consumption and the beast of burden; but this is not an important point in our discussion. The noteworthy thing is that, while it is a matter for our choice as to whether we propose to keep animals for food and draught, it is not really within our competence to decide for or against the keeping of animals for the third purpose -- that their waste products may enrich our soils.

The question whether an agriculture can afford to breed any animals for food has indeed been discussed; it takes a greater area and more intensity of effort to maintain such animals than to raise vegetable crops only; we know from our current experience that when scarcity threatens, we have to dispense with many animal products. The problem of maintaining or abolishing the draught animal also raises interesting queries as to the most suitable form of power in agriculture. But the continuance of the animal as enricher of the soil is integral to all we do; it is axiomatic and admits of no debate.

In our discussions we shall have the experience of mankind to guide us -- and also its mistakes. The best-established types of husbandry are correctly called mixed farming and are predominantly of the peasant type, though it is by no means essential that mixed husbandry should be carried on by peasant proprietors; there exists also large-scale estate farming which in every way conforms to the ideal of mixed husbandry. Our own country can show admirable examples and has an outstanding tradition, but such estate farming on mixed principles is found throughout France, Germany, Italy, Hungary, Austria and in many other countries. In fact, systems of tenure do not affect this question. There may be peasant ownership, a tenancy system, or large-scale proprietorship; there may be plantations by foreign capital and run under salaried management. To any or all of these or to any other forms of agricultural enterprise the principles of mixed husbandry may be applied.

By mixed husbandry is meant a husbandry which at the same time maintains animals and grows crops. It does not matter which is the end product aimed at, it does not matter whether the farmer finally wishes to consume and to sell corn, or meat and milk; in the one case he proposes to maintain animals whose manure will keep his fields fertile, in the other he sets about growing crops to feed his cattle; in either case he simultaneously carries on vegetable and animal farming and *never allows himself to do only the one or the other.* Moreover, he is careful to do so in the right proportions. True mixed farming depends on keeping the number of animals correctly related to the area farmed, not forgetting that the area farmed is not to be measured by mere superficies but is larger or smaller according to how much of the pore space of the soil is called upon; a farm, in other words, goes downwards as well as spreading over the fields.

These principles are the right ones. The first thing the agricultural world must see to is to secure a correct general lay-out of the farming of any given area; and this correct layout should be established not only over the country as a whole but within each farming unit. More especially is it essential to secure, if crop growing is intensified -- and our modern agriculture concentrates largely on this -- that the animal population should be enlarged in proportion. But the opposite also holds good; it is useless and dangerous where crops are maintained merely at extensive levels, where wild natural pasture is the only feed provided, to keep on adding to the animal population.

That is just as bad a maladjustment as to deprive the earth's vegetable cover of its animal co-partnership. Whichever mistake is made, the earth's green carpet will be twisted awry. Either the vegetable crop will have to draw from a soil lacking the components which build up fertility because there are no animal wastes, or the animal population will be too heavy on the land.

Our thesis then is this: every estate, every plantation, every farm should aim at being a true unit of husbandry; it should maintain that number of animals which is necessary to the area farmed; it should be, manurially regarded, self-supporting; it should provide proper feed for its own animal population. The balance, in other words, should be deliberate and exact and should not be governed by considerations other than those connected with keeping the land fruitful.

It is rather shameful to have to admit that immense tracts of our planet are so mismanaged as entirely to ignore this essential principle. It is indeed a confession of negligence, ignorance and carelessness. There are fundamental reforms to be faced, and not in one type of farming only.

How do these mistakes occur? Let us take first that type of agriculture which aims at the production of a special plant product in bulk, to be handled commercially as an export crop. Such agriculture has to be very highly organized. It works for a money dividend, the amount of which is the principal deciding factor. It is thus peculiarly open to the temptation of sacrificing the future for an immediately profitable present. Its best-known forms are the great plantation industries which produce tea, coffee, sugar, rubber, cacao, cotton, sisal, etc., but it also embraces such cultivation as that of the vine in the south of France or the cotton crop of Egypt. What do we find here? Highly intensified systems of plant cropping combined with an almost total absence of animals. Where peasant ownership still holds a few animals linger -- the mule in the southern cotton States of North America, the donkey in Egypt. But as organization tightens, as commercial interests get the upper hand, the animal becomes rarer and rarer. The reason is obvious. Animals are eliminated as inappropriate; they must make way for the special cash crop to be grown. Why keep pigs when another grove of cacao trees could be planted?

The argument at first sight appears sound, or at least clear and lucid. The answer is provided in the woes of the industries which have been tempted to yield to it. Practically every plantation crop can show a history of advancing disease. To add to their troubles, old valued species of the plants they grow are running out, in other words, fail to reproduce themselves) so that fresh varieties have constantly to be bred and introduced at great expense; an instance is the bourbon variety of sugar cane in the West Indies, which suddenly began to fail towards the end of the nineteenth century. It is the same story in coffee, cacao, banana, rubber and cotton. The complete collapse of the plant, bush or tree to be cultivated, the constant abandonment of areas, the frantic search for fresh strips of virgin forest, which are ruthlessly felled and taken over in order to maintain some sort of production, tell but one story -- that of a natural law so flagrantly violated as to put an end to all that is being attempted.

Such a disastrous outcome of the opening-up of the earth's surface is quite unnecessary. Most interesting might it have been to stand by the side of one observer in 1908 and again thirty years later, in 1938, and pick out an estate in Ceylon where at the first glance the cacao trees were seen to be in flourishing condition, where obviously all was well with the land, and to learn, as that observer did, that this was the only estate in the island which kept pigs and cattle to get manure for the trees. (The Kondesalle estate near Kandy; exactly the same observation had been made years previously in Grenada; see Howard: *The Soil and Health -- Farming and Gardening for Health or Disease*, p. 118.) The experience was repeated in the south of France; again the naked eye picked out instantly a slope where the vines were healthy (at Jouques in the Department of Bouches du Rhone; op. cit. p. 135); quite a special appearance forced itself on the attention in their massed glossy leaves and fine bunches, and inquiry once more established the use for years past of animal manure. The notorious history of the vine in Europe, the whole stock of which had to be replaced after 1860 from American sources owing to the ravages of the *Phylloxera*, should have made the European populations careful. But just as they failed to perceive that the Irish potato murrain of 1845 and 1846 was due to bad farming practice following on a disastrous elimination of tree growth, so did they fail to realize what the collapse of the vine might have taught them: that mono-crop, cultivation is a dangerous experiment and one that, if it eliminates the animal, is fatal.

Not for nothing is the Afghan tribesman content to place only about one-tenth of his area under vine; his sprawling plants running in trenches resist every disease; the rest of his land is devoted to fallow or to ordinary cropping. Such supporting cultivation should always accompany a commercial crop and on no niggardly scale. With its help rotations may be arranged, if necessary long-term rotations; above all, it must support an animal population of a size to balance the vegetable production of cane, banana, tea, coffee, cacao, grapes, or whatever it may be. The manure from these animals is the only insurance against disaster.

In the long run this will have to be done. To the tea industry perhaps may be paid the tribute of having been the first to set its house in order. The tea bush is a very strong plant and disease, though known, was not on a great scale in the tea gardens. A number of estates in India and Ceylon, where the bulk of the industry lies, have now introduced the animal and have greatly benefited in healthier bushes, and let it be added, it signally increased production per bush.

(The best example comes from an estate of the Duncan group, the Grandrapara estate in North Bengal for many years under the managerment of Mr. J. C. Watson. The estate carries 2-1/2 million tea bushes, and maintains 200 head of cattle. The making of compost, first started in 1934, has resulted in raising the average yield of tea per bush from 5.09 oz. [five years previous to 1939] to 7.94 oz. [average 1939-45]. Details in Howard: *The Soil and Health -- Farming and Gardening for Health or Disease,* Appendix A, pp. 265-269, "Progress made on a Tea Estate in North Bengal".)

Important as they are the plantation industries and similar types of cultivation cover only a limited portion of the earth's surface. What of the rest of man's efforts? The picture is a very mixed one, ranging from what is superb to what is only indifferent or even invites condemnation or contempt.

Perhaps the greatest expansion of agriculture which the world has ever known within a short space of time has been in Canada and the United States of America -- from the agricultural point of view these countries are a single area. There is here nothing of the plantation principle. Ownership is divided and each farm, or section, as it is commonly called, is owned and farmed by an individual who has every motive to keep his land in good heart and hand it on to his heirs in a flourishing condition. There is, therefore, what may be called family farming. The two countries have been proud of their agriculture, and it is a recognized fact that their national wealth is largely based on agricultural production, which rapidly advanced from about 1840 onwards.

It is tragic that these rich plains should now be cited by all authorities as the worst examples of worn-out land. The figures for the United States, based on the computations of the federal authorities themselves, have often been quoted; 61 per cent of the total crop area has lost its fertility, either in whole or in part; less than 40 per cent of the land won by the pioneers is still in a condition to be farmed with success. Thus in one short century this great country has forfeited threefifths of its natural agricultural capital. These losses are now beginning to be brought home to the population, no longer in mere figures, but in those dust storms and destructive floods which are the inevitable verdict on soil mismanagement.

Perhaps the original conditions were such as almost to invite soil depredation. The land was virgin. The native Indians had lived principally by hunting and fishing; their agriculture was casual and unimportant. The accumulated fertility was colossal and included immense animal enrichment. The old tales about the herds of bison which roamed the plains now sound like fairy stories, but they are well authenticated. This glorious animal population was most thoughtlessly and extravagantly slain. But the soil had by that time acquired such an intense fertility that it held out for from fifty to eighty years. It was only with the beginning of the twentieth century that exhausion began to show.

It must also be remembered that there was plenty of land. If one section showed lessened fruitfulness the pioneer could move on. Population was fairly sparse for several generations and it was not until closer settlement had been achieved that the results of exploitation showed.

The farming undertaken in the Middle West and West -- far less on the Eastern seaboard

-- was monocrop farming of an exaggerated kind. It repeated what had been done in the plantation industries with even less care, though the crop grown was different, a cereal. Year after year wheat was taken off the same ground not only without animal manure but without the rotation of root crops. The system of leaving fallow no doubt helped to maintain some fertility, but it is astounding that this continuous wheat-growing should have been possible on the scale practiced. The straw was not ploughed in but burnt as it stood, so that even this organic waste was not properly returned to the land. Where the farmer has his return from a single crop only it is obvious that this crop must be grown on a considerable scale if he is to live at all (there was so little to do after the wheat had been reaped that a large part of the farming population migrated to the towns during the winter). The North American "dirt farmer" was not rich. It was in an endeavour to live in the most simple comfort, not in any mad pursuit of unusual wealth, that he carried on his business. As might be expected from the system of agriculture pursued, and in spite of the stored fertility of the ground, harvests reaped were not heavy per area. It followed that to make a living a surprisingly large acreage had to be handled. To make this feasible, operations were simplified and mechanized to the last degree.

It is difficult to say whether the invention of the machine made North American farming what it was or whether the nature of that farming imperatively called for the machine. Machinery became at once an aid and a temptation. It was the boast of the farmer that with the acquisition of a suitable hook-up (the name given to all combinations of machines which can be attached to the tractor, often more than one machine at a time, whatever the operation to be done) he could by his own unaided efforts plough, sow and reap 640 acres (the original acreage of a section) or 1,000 acres or 2,000 or more. The help of a single "hired man" for a few weeks in the summer was sometimes, but not always, sought. An immense amount of thought, care and capital was put into the invention of agricultural machinery, in the making of which the United States still leads the world.

Machines have their legitimate place in our endeavour to make use of the green carpet. Agricultural operations are very laborious and the increase in efficiency which comes from replacing hand tools and animal draught by power-driven machinery is no small gain to us; one man can easily do the work of four. (This is a Canadian estimate of the rise in efficiency brought about by the use of machinery over a single decade. For ingenious calculations made by the Department of Agriculture of the United States, see a brief summary by the present author in Howard, L. E.: *Labour in Agriculture: an International Survey*, O.U.P., and Royal Institute of International Affairs, pp. 244 *et sqq.*) We could not nowadays do without the tractor in agriculture, certainly not without the binder, perhaps not without the combine, specialized though this machine is and only suited to certain climates. But if such machines pass over lands where not a horse, cow or pig is to be seen, then we have repeated in another type of agriculture exactly the same fatal error which has done so much to wreck the rich plantation industries. We come back to our original point, that the animal becomes our farming partner in more ways than one, and though we can do without him in one direction, we can never do without him in all. Abundant as is the animal wild life all around us, the birds, worms, insects, etc., we dare not depend on these for the fertility of our fields. For we are asking a great deal of the soil. We cultivate intensively and select our crops severely; we follow one crop with another. In this intensification and selection we are speeding up the cycle of plant life to an extent which we hardly realize. This is only possible in the long run if we keep the balance by maintaining also a suitable intensity of animal existence.

This is where the North American farmer -- and many other farmers -- have made their mistake. In replacing animals by machinery they forget the first law of Nature; they ignored the animals as a fertilizing agent. Some types of animal production were pushed to extremes, but always in particular zones or "belts" as they are named; the hog-belt, the beef-belt, etc. Here the aim was simply the animal end-product. There was a complete absence of the old European conception of mixed farming, where the vegetable crop and the animal population are kept in harmonious and intimate relation. The mistake is being made good. Mixed farming is being earnestly advocated by the authorities both of the United States and of Canada. But it is by no means easy to persuade a farming public to abandon practices which have been universal for generations; the passion for machinery has possessed the very heart of the North American farmer. He has been taught to be proud of it and he has had the reason. As ingenious instruments his machines could not be bettered. He boasts that the power machinery which ploughs and seeds and reaps and binds and threshes provides food for the modern world and the boast is not without foundation. It is the misfortune of the present generation that the account rendered by Nature is now due.

But the animal, besides conferring untold benefits on us, has also certain rights. Above all, he is entitled to proper feeding. Animals in the wild are sometimes starved, they often find it difficult to get sufficient sustenance and may roam hundreds of miles in search of it; their seasonal migrations for food are on a huge scale. The herds of bison which we noted in North America regularly followed each spring and summer from the south to the north of this huge continent what a farmer would call "the early bite", that is, the young fresh nourishing grass; on getting this particular form of nourishment depended the birth of their young. Of necessity we curtail such movements. Our animals do not roam; they are domesticated.

When the process has been finally carried out, the animal is too near us -- and far too valuable -- to suffer neglect. If any charge can be brought against modern animal husbandry where the animal is kept to assist human consumption, it is that of over-stimulation by an excess of rich food. The view is beginning to gather force that concentrates to stimulate the flow of milk in the milch cow, for instance, can do harm, the four stomachs of the ruminant demanding bulk -- its natural roughage; if not properly exercised this digestive system can easily fall a prey to disorders which lie at the root of many prevalent cattle diseases. Be this as it may, it at least exonerates us from one reproach, that of not finding an ordinary subsistence for our farming partners.

But when the process of domestication is incomplete, the danger may easily arise of a starvation against which the animal can no longer protect itself by natural means. Its roaming powers, if not entirely prohibited, are restricted. Simultaneously the size of herds is increased.

This is important. Nature decides, perhaps by cruel means, the size of the animal population appropriate to her green carpet; those in excess of the food supply perish. Man can, up to a point, contravene the law. He can collect, or cause to be brought to birth, a number of animals in excess of the appropriate measure. This originates a want of balance between the two component sides of the green carpet which is as great an error as the continual cropping of the soil in plants without animal enrichment.

The mistake is not widespread, but it does occur on quite an important scale, as it happens, in types of agriculture widely opposed to each other. It is a common experience to find in Africa that cattle are kept by the indigenous populations grossly in excess of the possible food supply. They are an accepted form of wealth, practically a currency. This currency is counted by numbers, not by the condition of the animals; many half-starved animals are worth more than a few well-kept beasts. The consequences are inevitable. The ravenous herds graze every blade down to the roots, thus killing the grass and rendering matters worse until disease and emaciation mercifully terminate their unnatural existence. The causes of this state of affairs do not lie in the practice of agriculture. They are economic and the reforms which clearly should be brought to the notice of the peoples concerned are a matter of social policy and outside our present discussion. The same may be said of the special religious tenents which affect the breeding and maintenance of cattle in India. Even more difficult questions are here involved. The results, however, in either case, have ended in a very serious maladjustment of animal population to food resources.

It is when we come to a thoroughly modern agriculture like that of Australia that we are astonished to find something of the same kind, and, unfortunately, once again on a large scale. The vast flocks of sheep maintained on the Australian pastoral ranches may run into hundreds of thousands. These flocks may be described as semi-domesticated. From time to time they are "mustered", as it is called, driven to the shearing stations and shorn. For the rest of the year they graze off the countryside.

As long as there is plenty of grass all is well. It is when the rains fail that these flocks are decimated. The sheep then perish by the hundred thousand, less from want of water than from want of food. For they are entirely dependent on the natural pasture. Their numbers are too great to allow of supplementary sources of food being grown for them; so Australian farming practice dictates. When the drought comes both masters and beasts are helpless.

There is here what may be called a lack of perspective. Such immense flocks are in proportion to the food supply only in good seasons; in bad seasons the animal population becomes altogether excessive, and Nature, exercising her undoubted right, removes it and restores that balance which she always observes in relation to her green carpet.

There is no question but that we have here a fundamental error. Such repeated dangers and disasters as attend the Australian pastoral industry are not a part of a proper farming system. It is scarcely to be wondered that the wealth of the sheep-rancher is a by-word for its instability; immense fortunes are easily accumulated and may vanish in a season. This is a contradiction to that continuity of effort and that reasonable permanence of reward which ought to accompany the farmer's career. (The same mistake of overloading the pastures with too many animals was at one time made in the pastoral industry of the West in the United States of America. See Paul B. Sears: *Deserts on the March*, pp. 65 *et sqq.*)

A lack of proportion between the size of an animal population and the volume of crops grown has often to be guarded against in farming. It arises insidiously. The examples described are outstanding because they exist or have existed on a large scale and over considerable periods, but they are not only ones which could be cited. Wherever the sense of the close interrelation of the animal and the plant has been lost, agriculture is liable to go astray. Not that every single farming enterprise can at all times be self-sufficient. In spite of the general principle which we laid down above, that each unit of farming should be manurially regarded self-supporting, there are many specialized forms of enterprise which must make demands outside their own limits; the idea of exchange need not be wholly forgone. Indeed it would not be practicable to preach so severe a doctrine; there must be give and take. It is where a whole section of the farming world allows itself to be pushed into a position of thoroughgoing dependence on some other interest that weakness arises.

Each situation requires to be judged in the light of circumstances. It would not be reasonable to expect the ordinary small allotment holder on the fringe of a city to keep the animals, even the poultry or rabbits, needed to supply the manure he requires; such an undertaking is usually beyond his time and his resources, and it is quite proper that he should call on others for his rotted dung, or failing that, on the municipal authorities for prepared compost or for bags of dried activated and digested sewage sludge. Whether the commercial market gardener is well advised to carry on his highly intensive cultivation by buying from outside sources what he must have to complete his heavy manurial programme is more open to question. His position is not what it used to be. In the days of urban horse traffic his wagons were able to bring out on their return journeys the horse manure of many city stables. With the disappearance of the horse in favour of the motor, this is no longer so, and his position would be safer if some animal farming like the keeping of pigs were regularly conjoined to market gardening enterprises; this would mean a new effort for a very busy and very competitive industry and could not be brought about easily.

But it is when we come to such a practice as that of supporting a whole animal population from quantities of oil seed by-products imported from the tropics that we are face to face with something really questionable. This traffic assumes not only a huge total volume but crosses international frontiers which are of a very special category. The countries growing the oil seeds are undeveloped, the home of primitive and as yet uneducated peoples, the importing countries are old civilized countries. The accepted theory is that the older countries pay for what they get by sending back manufactured goods and that this is a fair exchange.

From the agricultural point of view the opposite is the case -- the so-called exchange is sheer robbery. What is happening? The age-old virgin fertility of these vast tropical regions is being exploited or mined, a process bad enough in itself, but a thousand times worse in view of the fact that the results of this exploitation are dispatched overseas; the worn-out lands of Europe are being propped up to maintain their rich animal population not by any reform in their own agricultural practices but by using up the natural wealth of distant parts of the earth . The return of manufactured goods is no compensation. The peoples who are thus being deprived of their greatest inheritance are not in a position to understand what is happening or to defend themselves. So far no public pronouncement has been castigating this specialized form of international banditry.

In what other ways can the animal enter as partner into our farming practices besides those of yielding it as products for our consumption, drawing our implements, and enriching our soil with its waste products? Of these three ways we saw that as to the first two we can exercise our choice, whereas in the case of the animal as an enriching agent we can only obey natural law and never lose sight of its importance for this purpose. There is yet one more direction, however, in which the animal can be asked to co-operate with us.

We can call on the animal to help us in passing judgment on the quality of what we grow, in other words, to help us in deciding on the success or failure of our farming. There are innumerable subjects on which we can ask the animal to give us an opinion. This questioning of the animal needs a certain skill. To do it we must first efface ourselves; we must then pose the question rightly, provide the correct conditions, and finally do nothing but watch. We must also have the understanding to read the answer, which can afterwards be tested and re-tested by any means which may seem appropriate.

Up to a point this device has long been a part of the farming tradition. In the plant we have the accepted inquisitor of the soil. The growing plant gives an account of the soil from which it derives in terms which none can dispute. Every farmer is guided by this advice. Indeed, an experienced cultivator has only to be able to read it like a book; so revealing is the vegetation that he scarcely needs, or only for confirmation, the services of the soil analyst. In any case, he will get his first and major inkling of the truth from this sort of observation, and will be extremely chary of accepting any opinion from his human advisers which might appear in contradiction to the testimony of the plants.

If the plant is the best judge of the soil in which it grows and is perfectly prepared to tell us every particular of what it has found out, so also is the animal the finest expert in the world. It will eat the plant and without payment, without complaint, without hesitation, and with absolute correctness will inform us of the continuation of the story, namely, the state and condition of the plant. In the ordinary exercise of animal appetite and in the resulting condition of the animal we have the most complete, final and decisive instrument we can need for judging our ideas and theories on crops.

The animal's choice of its own food is a certain test between different crops. Its satisfaction in what it, eats is another. Health, stamina, what is known to the farmer as bloom (good shape, good stance, alertness, brightness of eye, beauty of skin) and finally the maintenance of reproductive power will be its further replies to our queries as to whether our crops are good or only indifferent. The animal is even more useful to us as an indicator than the plant. It has the power of locomotion and therefore the power of obviously looking for its food and of choosing or rejecting. Its verdict is unmistakable and immediate. Perhaps also it has less ability than a plant to adapt itself to unpleasant circumstances, which means that the results of these are more quickly visible in its altered condition; a plant will survive the most extraordinary way and has a tenacity, which the higher organism rather lacks. Thus the use as guide and mentor of the animal, so close to ourselves in its habits, strength and weaknesses, is always illuminating.

One acute observer claims to have been more than once informed of lime shortage on his land by seeing his hens and ponies worry at the loose mortar in the old walls -- they had found the pasture lime-deficient; when, on the contrary, they merely picked up and dropped little pieces of plaster thrown to them he knew his grass was in good fettle. (Michael Graham: *Soil and Sense*, Faber & Faber, p. 149.) Nothing could exceed the simplicity of this small test, but could it be improved upon? The obvious way of getting an answer from the animal is in truth to watch it at its food. We have already referred to the grazing animal's preference for the grass near the hedgerows and deduced the probability that in these strips of pasture the animal had found the minerals it required. (See Chapter 4.) When pigs, poultry, dairy cattle and horses consistently take 15 per cent less food grown on a humus-fed soil than food bought in the open market, we may legitimately assume that the feed produced by the new method is more satisfying; when the animal's health obviously improves we can draw even more important inferences. (On the late Sir Bernard Greenwell's estate at Marden Park in Surrey. The results were described in a paper read by Sir Bernard to the Farmers' Club on 30 January 1939. Among other results infantile mortality among poultry fell from over 40 to less than 4 per cent. In both this and other cases the reform in farming practice was based on the use of compost.)

Use has lately been made of the animal's instinct in these matters to prove the difference between the effects of various manures. Recorded instances are of interest because they seem to be so definite. Thus out of six fields equally open to access a herd of cows consistently refused to graze the one which had received a dressing of artificials. (At Heversham in Westmorland; *Compost News Letter,* No. 3, pp. 18-20. There have been other instances.) Or again beasts once fed on swedes grown without artificials found those which had been grown with these fertilizers most unpalatable. (At Booton near Norwich; *Compost News Letter,* No. 3, p. 13.) The instinct is as unmistakable in the smaller animals as in the larger, in the domesticated animal as in the wild. cats refusing boiled potatoes grown with artificials will eat avidly those grown with compost (Balfour: *The Living Soil,* p. 127); rabbits show the same sort of preference *(Compost News Letter,* No. 3, p. 13) and even rats are stated in their depredations to prefer the corn-bin holding the superior grain. (Ibid., No. 10, p. 46. Supporting evidence on the points raised will be found in Howard: *The Soil and Health -- Farming and Gardening for Health or Disease,* and in the quarterly periodical *Soil and Health*.)

In the case of the rabbits we are told that when fed on the feed which they obviously preferred they changed from a state of listlessness and a condition of smelling unpleasantly to become vigorous and sweet-smelling. Not only an animal's appetite, but its bloom and condition -- those final tests of health -- are an answer to many questions. Can it be doubted that in this way the animal tells us most of what we want to know? It reads the earth's green carpet for us like a book, page by page, with the most minute care and with complete readiness, in a way which is utterly beyond our powers. We may be sure that a crop is good if our animals flourish on it; if they continue to do so then our farming system is reliable, our results may be accepted with confidence. Even the scientist may be satisfied with such a test. Nothing so conveyed to the director of one experiment station in the East the confidence that his system of soil management was correct as the outstanding condition of his work cattle, so splendid in appearance that they were the pride of the countryside. His flourishing green crops had told him much; they stood out from the surrounding countryside. But his cattle told him more; they enforced the lesson with dramatic lucidity; they finished the story which the crops began. (Sir Albert Howard's cattle at Indore in India; see Chapter 9.)

The use of animals for the purpose of revealing to us our success or, if need be, our failures could be much more widely undertaken. The tests which our farming partners can so well carry out for us will be tests in the open field under natural conditions. This will be an advantage over the ordinary laboratory nutrition experiment, for animals are so sensitive to environment we never quite know how much influence an unusual surrounding can have on what they do. In carrying them out a major part of the work might be done by pioneer landowners, who will be found only too glad to place their land and herds at the disposal of the scientist; that is proved by past experience, which should be sufficient to dispel the illusion that the farming world is unwilling to co-operate in research; the contrary is the case. It will be for the scientist to pose the questions to be put; this the greatest step in all research, is his business, and on his imagination and grasp of the subject everything will depend. The principle of asking the animal to co-operate should terminate the grossly exaggerated fragmentation into which agricultural research has allowed itself to fall; work on plants and animals should not be so rigidly demarcated as at present nor so formally allocated to different experiment stations. On the contrary, the breeder of wheats will make a point of keeping fowls to test his grain, the poultry expert will grow his own barley, or suitable exchanges of products from station to station will be arranged for the same end. For if Nature knows nothing of the divisions which we have set up, it behoves the scientist, as it behoves the farmer, not to ignore her teaching, never to flout her law. The animal is our farming partner, and no practice and no knowledge which ignores this fact will contribute anything to human welfare or, indeed, will have any chance either of usefulness or of survival.

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The Earth's Green Carpet

By Louise E. Howard

Chapter 6
Gains and Losses in Fertility

Our discussion up to this point has turned first on the tree and then on the animal as the two great agents appointed by Nature to maintain the fertility of soils. The work done by the tree is supplemented by the smaller plants, the various types of which compete over the surface of the earth, contributing each their share to this great project. If the tree is the most important creator of fertility, the shrub, bush, plant, moss, lichen, algal film are not far behind it in efficiency.

We noted also at the outset of this book that this diversified vegetation is distributed by Nature in perfect adaptation to the different soil formations which have gradually developed out of climatic and geological conditions. The same is true of natural fauna; wild animals are distributed so as to be adapted to the regions which they have to inhabit and the conditions there prevalent. The combined result of this plant and animal distribution is that we find in Nature a wide variation, and this variation is a variation in the intensity of existence, at one point Nature causes her Wheel to revolve at a great pace, at another it slows down to an almost imperceptible motion.

The alterations which come about in climatic and geological conditions, then in soil formations, and finally in the flora and fauna adapting themselves to these changes, are slow. The forest may become the marsh, then sink and lie buried as the coal-field while other vegetation flourishes at the level of light, the bog may form the peat deposit, the river may silt up and form the bog, the mountain slope may be eroded and give way to the glade or bare pasture; but all this is done at that unhurried pace which we originally noted as characteristic of Nature's proceedings; these alterations may take centuries.

One of our major interferences with the natural round is to induce instead of these slow changes a succession of rapid transformations. Not only do we put the field where the forest once triumphed, drain the marsh and re-sow the pasture, but every three or four years, or every year, or even two and three times in the course of a year we ask the soil to grow a different crop. Now each crop adds to or takes out, usually both together in a very complex way, something affecting the constitution of the soil. In other words, we are always bringing about small intense rapid alterations of the levels of soil fertility.

We claim to know what we are doing. In reaping our harvests of barley, oats or wheat we assume that we can count what mineral and organic elements we have extracted from or added to our fields. Indeed, agricultural science now declares itself able to measure such things in exact terms, in pounds per acre of the different elements withdrawn, or alternatively is prepared to state how much of nitrogen, potash or phosphorus -- these are the three great fertilizing elements -- have been left in the fields in the form of roots, stems and straw, or are being added in the form of green crops, organic wastes and animal manures. The business of computing all this, of keeping track of the levels of fertility in our fields, is an old one, first carried out by rule-of-thumb and now the special care of the soil scientist, who advises the farmer on the points that arise. So far so good. We have here the heart of the farmer's knowledge. What eludes us are the long slow changes which in spite of all our care are apt to overtake our cultivated fields.

These long slow changes take place everywhere where man has settled and the majority of peoples have suffered from them. This expression may advisedly be used, for the changes are too often those of deterioration. If at the outset of our efforts we succeed in quickening the intensity of the natural cycle, as is undeniable when we make a natural prairie arable, drain a marsh or turn an odd bit of ground into a vegetable garden or a fruitful orchard, in fact, when we do anything at all to substitute our highly cultivated areas for natural wilderness, this seems too frequently to be followed by a slow, silent, unnoticed decline. A few nations have succeeded in maintaining, some for unknown periods and one -- the Chinese -- for forty centuries, a standard of fertility in their fields equal to the one from which they started; most nations have had to face the exhaustion of their soils.

For what we do is rather daring, and unless the utmost skill is available many mistakes lie ahead. Human history could be written in terms of success and failure in keeping abreast of this problem. If we had enough facts we should possibly be able to see how one civilization after another slowly declined with the declining energy of its peoples, inadequately sustained on deteriorating soils. Was the fall in turn of the Persian, Greek and Roman worlds due to that simple act of the devastation of forest life in the areas which were the cradles of these great races? We know most about Roman agriculture, and the story undoubtedly reads as one of the decline of agriculture, a decline of which this people was itself conscious and which its leaders and writers deplored and did their best to stem. The Roman story is tragic, for at almost any point the tide might have turned the other way. For in all this long and chequered history of the human race revival is frequent. At no point the breakdown inevitable. There is no fate or destiny hanging over humanity which bids us vanish from the face of the earth. The fullness of the earth is ours to hold if only we can learn to guard and store its treasures.

There is, therefore, no need for pessimism, which is quite misplaced in considering the facts before us. But that we need to learn some lessons may be conceded. The history of our island will form a good subject for a first analysis.

The start begins before the Roman occupation with the colonization of the south-eastern portions of the country by Belgic tribes. They brought with them the heavy mouldboard plough and were skilled farmers. They grew wheat, an exhausting crop, and exported it to Gaul. But only part of the country was cultivated, namely the lighter soils of the downlands, which were alone fit for habitation, the rest being marsh or forest. The Romans brought little change except that they introduced the villas which were large farms under single ownership run by functionaries, resembling the *latifiundia* of Italy against which the Roman writers rail so unavailingly. The exhaustion of the soil continued, for the demand for wheat (the staple food of the Roman soldier) was very great; in the time of the Emperor Julian no fewer than eight hundred wheat ships left for the Continent.

This organization was largely destroyed by the Anglo-Saxon invasions. The new settlers brought their own system of farming, which was above all a communal one centered in the German village from which the manor was evolved. They too used the mouldboard plough, which finally ousted the lighter Celtic scratch plough. Invented to deal with the heavy soils of the Slav countries it had made its way across Europe and was finally established in our island, where its use has continued until to-day. Its main feature is a high penetrating power, which undoubtedly enabled cultivation to be extended by slowly carving out the valleys and plains from the surrounding forest land. But its very power caused a too rapid oxidation of the available soil humus, which was not easily replaced by natural recuperation processes in a cool damp climate and which was further hampered by bad drainage and shortage of manure. Of this there was never enough, for without root crops only a few breeding animals could be wintered, while what accumulated was largely taken by the lord of the manor on customary right to enrich his own demesne.

The result was a slow and gradual exhaustion of fertility. There was not, it is true, a complete degeneration into the desert conditions such as came about in Mesopotamia and in the Roman-occupied lands of North Africa, but the harvests gradually dwindled and finally failed to suffice for the needs of the population, which was growing. For many years plagues and pestilences, accompanied by murrains among the animals, succeeded each other, leading up to the scourge of the Black Death in 1348-9 and in the succeeding years of the fourteenth century. One-third to one-half of the population perished. The very magnitude of the disaster provided a remedy, for labour became so scarce that manorial farming began to collapse and many fields had to be enclosed and laid down to grass. This gave the land a long rest; moreover, the pasturing of sheep provided considerable sources of animal manure. The soils of the country slowly recovered; fresh stores of humus were formed under the protecting grass carpet.

When increasing population led again to the breaking up of the enclosed grassland for tillage, the land was able to respond. A long period of what is called enclosure replaced the open fields of the communal system. It had the advantage that fields could be fenced (enclosed), animals thus maintained in sufficient numbers and the land in general managed on improved systems. The cultivation of clovers and introduced grasses, the bringing in of the turnip by Townshend in 1730, led later to the great improvements in livestock due to Bakewell and other pioneers. Better animals gave more manure, more manure meant richer fields. An important accompanying reform was the replanting of trees, largely following on the publication of Evelyn's *Sylva* in 1678. The culmination of this progress is seen in a very greatly improved system of rotations, which kept the fertility cycle infinitely more balanced; turnips were used to clean the ground and clover to trap the atmospheric nitrogen, the various stages being skilfully combined and leading up to each other in the famous Norfolk 4-course system. The Townshend reforms were popularized by Coke of Holkharn (1776-1816), who was a great landlord and a great leader.

But the enclosure movement, excellent though it was for the land, had been hard on the rural population. Many were ousted from possession, their livelihood was gone. The dispossessed formed the beginning of that huge army of general workers whose existence is in itself a factor in the situation, for such people have to be fed. Moreover, in order to buy their food they must work. Either there would have to be a starving peasant population, far too many for the land, or some other means of sustaining life had to be sought.

This means was found in industrialization. The dispossessed craftsmen of the old rural communities migrated to the towns and began to make industrial products. Then began a hunger of the cities and a hunger of the machines which put intensive pressure on farming. Many improvements were made; drainage and transport and implements were attended to. Real advances were instituted) accompanied by one retrograde step, the introduction of artificial fertilizers. On the whole, a period of great apparent prosperity for farming set in, for in spite of the sweeping away of the Corn Laws in 1846 and the free introduction of cheap wheat, there was enough demand for the other products of farming to carry the farmer along. The country was heavily stocked with beef and dairy animals.

But the great depression of 1879, which dealt such a heavy blow to British farming, showed up the weakness of the system. Two or three completely wet seasons ruined the farming world by ushering in epidemics of disease. There had already been many warning signs; the potato epidemics of 1845 and 1846, the cattle murrain of 1866 when one out of every ten head of stock perished. The returns of fertility to the land were not really sufficient to balance the demands being made on it. Since 1879 matters have become worse; a general decline of farming has set in. The outbreak of the Second World War has brought only rather desperate attempts to cash in the remaining stores of fertility accumulated under our grass carpet; for this purpose not even the most famous permanent pastures have been spared.

What then has really happened? We can rather clearly see the course events have taken. For the first half of our history we kept going at a low level of prosperity, using up too ignorantly and too fast the stores of virgin fertility recovered from the forest. The Black Death saved us, for the simple reason that it forced us to allow Nature to restore the natural grass carpet and with the grass carpet the humus content of our soils; this ushered in four or five hundred years of gradual improvement, culminating in the farming of the late eighteenth and early nineteenth century. The decline from that point was due to a faulty agriculture; more was being taken out of the soil than was being put back. In spite of some reforms this process is continuing to-day.

That our own agriculture has had this long history with its remarkable ebb and flow between conditions of soil exhaustion and soil fertility is instructive. We know the facts and can relate event to event. In spite of the many disasters which we have noted we may yet say that British agriculture has held its own in a wonderful way and its rather too low state at the moment is not necessarily permanent; it could easily lift itself again. Our island could regain all its inheritance of natural wealth.

Can we analyze any other systems of agriculture so as to throw light on this subject? The Incas of Peru are often cited, and certainly their agriculture is interesting in showing to what extraordinary perfection mankind can bring the cultivation of the earth against incredible odds. The amazing thing about the engineering feats of the Incas is that these were carried out with stone tools only. Their farming is known as staircase cultivation because they constructed stone stairways of terraced fields up the vast slopes of the Andes, tier on tier, sometimes as many as fifty in number. The construction was perfect; even to-day a knife blade cannot be inserted between the stones of the retaining walls, so accurately are they fitted together. When this construction work had been finished, coarse stones covered with clay were laid in the terraced spaces; then several feet of soil were added, which had to be brought from beyond the mountains; the small flat fields thus obtained were very slightly sloped for irrigation. The water for this purpose was brought in stone aqueducts, of which one at least ran four to five hundred miles; these may still be seen many hundreds of feet above the valleys.

Agriculture was thus successfully carried on in steep narrow valleys which might have seemed to present an almost hopeless proposition. In reality, a series of gigantic flowerpots were built, and in these was grown the food to support a nation which, as we know, reached in many respects a very high standard of civilization. Whether this agriculture had any rise or decline we cannot say; the culture of the Incas perished suddenly with the Spanish conquest. As they stand, the remains portray it perfect. They prove to what an impressive standard cultivation can be brought when there is a sufficient determination on the part of some human community to do so.

We might almost doubt the evidence of the Inca remains were they not confirmed by an existing example which seems to resemble the Inca system very closely, namely, the agriculture of the tribesmen in the Hunza valley of the Himalayas. This is equally interesting and will be referred to hereafter (see Chapter 9). But we are not restricted to these two examples, one in the distant past and the other on rather a small scale, if we want to study the best in agriculture, if we want, in other words, to study the conservation of soil fertility. The agriculture of China is still in being for us to watch after four thousand years; over this truly immense period it has kept the soils of that country at an even, and a very high, level of fertility. This is an outstanding fact. The more we reflect on it, the more remarkable it becomes. No other civilization has approached this longevity, and though we of the West may find what does not please us in some aspects of Chinese history or politics or ways of life -- usually we are more disposed to admire than to criticize -- yet when we look at the manner in which the Chinese race has managed to turn the earth's green carpet to human use while never once abstracting or despoiling the capital riches which Nature bestows on each constantly succeeding generation of men, we must admit that criticism has nothing to say and that a humble desire to learn from this people should take its place.

Chinese agriculture is outstanding in its attention to detail and above all in its old empiric wisdom. The special features of this agriculture are: the practice of mixed crop cultivations; the return of wastes to the land; the presence of the pig; the unabashed use of human nightsoil; the enormous labour spent on reconstituting the fields; the application of the principle of composting and the device of the compost heap. The result is an agriculture which is usually described as a kind of extended market gardening.

The fields are small, while the total amount of land on which a Chinese family can sustain life is incredibly limited, about one-third or one-quarter of what we require; this is possible because the agriculture is unbelievably intensive. Such agriculture shows how cultivated areas can be increased by adding to the pore space of the soil. In China not only is the ground never idle, never uncovered, but it is usual to intercultivate two or three crops together; one is being taken off the ground, one is maturing, one is coming up. Either the various drills alternate or the crops are actually mixed; mixed cereals are commonly sown (also in India); these are hand-reaped at their various stages of ripening. In vegetable growing a single plant of each sort will be put in together. It has always been supposed that plants were compensatory to each other in what they took out of the soil, but it has been left to the Chinese to draw the logical consequences from this idea, to imitate Nature's confusion as far as can be done, to plant as many different things together as can well be managed; our own practice of the rotation is clumsy by comparison. The Chinese system implies a vast amount of hand labour, but it is, at any rate, highly successful. It is carried everywhere by the Chinese settler as part of his stock-in-trade; wherever he may find himself he proceeds forthwith to mixed-crop growing.

He also keeps his garden and his fields extraordinarily tidy. Every unwanted leaf or blade of grass, every stalk and twig is collected. There is a certain putting aside of the larger stalks for fuel, which in China is cruelly scarce and a great problem. Indeed, the search for fuel inflicts some injury on Chinese agriculture by withdrawing the woody materials, but the population has to acquire some means of heating. Otherwise everything whatever of a vegetable nature, either wild herbage from the canal paths and hillsides or all the waste that comes from cultivated crops, goes back on the land.

Simultaneously with this there is always pig manure. The Chinese peasant does not contemplate farming without the pig. The pig is ubiquitous throughout the country; his flesh is eaten and his manure is the indispensable basis of farming practice. This manure is invariably supplemented by the whole of the human nightsoil. No sewage of any kind reaches the canals or streams; the Chinese never look on human excrement as something to be quietly and decently got rid of, they look upon it as a valuable substance and treat it accordingly. It has a definite commercial value. (The nightsoil of the city of Shanghai was worth $31,000 gold in 1908.)

From the wastes collected off the farm or the wayside and from the pig manure and the nightsoil is built up the compost heap; the materials of the heap, mixed, watered and worked by human labour, gradually crumble down into a rich humus which is then spread on the fields. Composting is an alternative to manuring, to which the Chinese cultivator does not often resort. (There is, however, a considerable use of dried human nightsoil not composted with vegetable wastes. This may be due to scarcity of the latter. The results are disagreeable and dangerous to health.) In our next chapter we shall have fully to explain the principles on which composting rests. Here it is sufficient to point out that the device of the compost heap is a Chinese idea, and is one of the most brilliant inventions which has ever helped man to use the riches of the earth. The compost heaps or the materials to be composted (all very neat) are seen everywhere, in the fields, in the village streets, on the canal banks. The method of composting differs, as might be expected in this huge country. The heaps do not usually run to very high temperatures (see Appendix A on this point), but a very complete breaking down is obtained, ending in a kind of pulverization. The immediate advantage of the compost heap is that it saves time and space. By building the heap upwards far less superficies are used for the creation of fertilizing material than would otherwise have to be given up; it also permits a speeding-up which is phenomenal; the two or three crops we have mentioned are possible because the Chinese cultivator is always dribbling a little compost round his plants. The fertility cycle rushes along at top speed, but as the land is always being supplied with fresh food materials it is never over-worked.

Whether in the long run the soil could hold out against this intense cropping is a moot point. A further instalment of ancient wisdom has taught the Chinese peasant not to run this risk. He has achieved the art of actually replacing his fields. It is a normal practice to dig out the rich mud from the canal and river bottoms and spread it over the land. This has to be done with spade and basket and the labour involved is colossal. But the cultivator is not deterred. The mud from below a village site is specially sought after, possibly because of the soap content (there is, as stated, no sewage content). In one part of China soil is regularly interchanged by means of hand labour between mulberry orchards and rice fields. The mulberry tree has huge roots and is thus the perfect instrument for pulling up subsoil just those elements needed for cultivation; the use of the soil from these orchards is an admirable way of restoring the mineral content of a depleted area. Altogether a colossal expenditure of labour is given to the composing and recomposing of the fields and of the soil in them, furrows and ridges being freely changed about and the soil generally moved and handled in a way which is quite foreign to our agriculture. Both men and women take part in this laborious work, which is the very *sine qua non* of Chinese farming. When the field has been constituted, though ploughing is shallow, the working on the soil is continued; each plant is separately cared for and soil and plant are put into perfect relation with each other.

By these practices China has avoided the exhaustion of her fertile soils. She has outlasted all the other civilizations of which we have knowledge because she has cultivated and conserved at the same time. It may be said with truth that there is no agriculture like the Chinese. Indian cultivation, beautifully carried out though it often is, does not approach the intensity of the Chinese, the compost heap being unknown; the result is a much less well-fed population. Japanese agriculture is clever and closely resembles the Chinese, but the Japanese have to wrestle with contours and natural conditions which are very different from the Chinese and which forbid the same tremendous development. The Chinese have a wonderful country, but in truth it is partly of their own making; the thousands of miles of canals, the ponds teeming with fish, the rich neat fields growing crop after crop were not given them ready-made by Nature; the materials only were supplied and close observation of natural laws, unstinted industry, unflagging patience were needed before they were welded by the labours of generation after generation into this perfect picture.

These analyses of agricultural systems have been summarized, but they will suffice to indicate two things. The first fact conveyed -- and this we owe to the Chinese, to the tribesmen of the Hunza valley and the Incas -- is that it is possible to cultivate the earth intensively and yet to maintain fertility. The second fact, which we owe to an examination of our own agricultural history, is scarcely less important; it is possible to restore lost fertility by adopting the right means and by taking sufficient trouble. The presumption is that the agriculture which can do this is more or less sound. A very faulty agriculture is a more difficult proposition, for fertility may be so completely destroyed that erosion has begun; the whole topsoil may have vanished; obviously to re-create a topsoil is no light task. But provided the topsoil is still there, however injured, it can be revived and usually with some speed.

Broadly speaking the agricultural systems of the world fall into four classes. There are the agricultures of the East, headed by the Chinese, but closely followed by the Japanese, the agriculture of Java, etc. These Eastern races have all evolved systems which may best be described as keeping the soil intact. Then comes the great agriculture of Europe, for it is great. But it is also very unequal, showing not only a remarkable variation of intensity-and this even within the single countries, with great losses arising out of poorly cultivated areas -- but also most disconcerting movements up and down; at one moment it appears to be advancing, at another, rapidly declining, and can sink very low indeed. This instability is a marked characteristic and shows that there is some inherent weakness, a weakness which exerts great influence on our mental attitude; we have no certainty in our agriculture and our discussions invariably reflect this. With European agriculture may be classed much of the agriculture in the newer parts of the world, which have drawn their populations from Europe. Thirdly come systems which scarcely merit the name of agriculture. They are sheer exploitations and are usually described as mining the land. We have already mentioned this topic and need not dwell on it. There are many forms of it, nor is this robbery to be imputed to any one nation, one period or one interest; we have all alike contributed something. Finally, there are forms of primitive agriculture. There is still a great deal of this in the world. It is difficult to classify, often conserving fertility though on rather a low level, but almost as often destroying it by wasteful systems of shifting cultivation.

It will be well to concentrate on what we have called the European system, because this is our special concern. Some further aspects of Eastern agriculture will be considered in our final chapter. We noted how apt European agriculture was to advance and recede, and how it varied within itself. There must be a range of soil fertility in Europe embracing almost every degree of good and bad. When one area or country seems to be rapidly on the downgrade, some effort is made, some fresh idea is brought forward and progress at once takes place; fertility is either restored or notably advanced. The recent opening up of the Campagna is a good example. At first an important food-producing area it then lay derelict for centuries; a few years sufficed to restore it to all its old capacity and probably much more. The same thing was done with our Lincolnshire fens under the Stuarts. There are innumerable examples of such projects, which are almost always successful; it is rare to find a failure. This shows that the inherent fertility of the European soils is still in being; it also shows that we are capable of making it available. But what perhaps is really more significant than these large-scale projects are the day to day small improvements being carried out on every well-run farm or estate in our continent. A marsh drained here, a water-course controlled there, an avenue planted, a field contoured, a vineyard terraced. The efforts thus put forth by farmer after farmer or owner after owner amount in the aggregate to one colossal determination to maintain, conserve and, if possible increase fertility; to these efforts the soil responds.

Why have the soils of Europe the capacity both to lose and to recover so remarkably under human cultivation? The answer lies partly in natural conditions and partly in ourselves. Partly in ourselves, because in spite of much carelessness and neglect and many errors we have managed through the long course of our history to keep the plant and the animal in some sort of relation to each other. Our European agriculture is based on mixed farming, a term which has already been explained (see Chapter 5). In doing this it follows one of the most important of all natural laws, one which is the very basis of the fertility of soils. We shall have a great deal of criticism to direct later against our ways of managing the use, of the waste products we get from our animals, but to have kept this animal population for two thousand years and to have distributed it throughout the whole area in proportions well adapted to the varying conditions has been our triumph.

It has been a mixed animal population, and this also has been to the good. In grazing, for instance, different animals take different parts of the grass for their food. Their mouth and lip formations are not the same, and they graze more or less closely. They also have varying preferences and dislikes; some animals cannot be got to touch coarse grass, others will eagerly clean it up. The way they graze will affect the way their dung and urine come to be distributed over the field. (A good popular account of the problems of grazing will be found in Michael Graham: *Soil and Sense,* Chapter 8, "The Animals".) The art of the grazier consists in allowing the various animals to enter and roam the field in such a way as to insure that they take what they want not only without damaging the herbage but so as to maintain and, if possible, improve the grass. The skill displayed in doing this can be the study of a lifetime. Success can only come with knowledge and experience, but there is also a kind of flair or instinct for getting the best results which distinguishes the good grazier. What is interesting is the conscious recognition of the fact that the grass and the animals are one project and the care taken to manage the various stages of growth or consumption of the sward in relation to the different types of animal to be maintained. In the management of grassland the English farmer stands pre-eminent, but it may in general be said that the relation of the animal to the soil is well understood throughout Europe. This has greatly helped to conserve fertility. Unless for some reason the animal population sinks very low, there is in the soil a reserve of animal enrichment which can always be called upon.

But we have also been greatly favoured by natural conditions. Because our continent lies in a temperate zone with plenty of moisture it has a natural grass cover. Though it is true that the tree would oust the grass if it were allowed to, yet the grass has a tremendous strength of its own. We are so accustomed to see grass spring up everywhere that we scarcely pay attention to this; yet it is a most important fact.

What does grass do to the soil? The answer can be given in three words. Grass protects soil. It protects soil from wind, sun, rain and all the forces of Nature, from burning, drifting, flooding. If the humus of the topsoil has been called the skin of our planet, the grass is like a skin to a skin. We might even press this analogy further; as the animal breathes, exudes and drinks through its skin, so does the topsoil breathe, exude and drink through the grass. And, like skin, the grass with rough usage can become tough, hardened, and almost, as it were, leathery.

The protection afforded by the natural grass cover in temperate climates can hardly be exaggerated. It has been calculated that soil without a grass cover wears out more than four times as quickly as soil protected by grass; some estimates put the contrast in rates fantastically higher. Such calculations may be speculative, but it cannot be denied that soil without grass is exposed to risk whereas soil under grass is safe. It is anchored, it is kept aerated, it is pulverized by the fine combing action of the grass roots; above all it is kept both moistened and sweet, and it is also fertilized because it is constantly using the sunlight to build up a supply of vegetable wastes.

Grass keeps soil moist and sweet in a very simple way. In a forest the rainfall seeps right through the ground to a considerable depth and in doing so carries with it the dissolved calclum carbonate and soil salts; the forest humus is therefore apt to be acid. In a desert, on the other hand, the hot surface actually draws what water there is in the soil to the top, where evaporation takes place, sometimes leaving the salts which accumlate; the sand of many deserts, therefore, is apt to be alkaline, sometimes excessively so. But in the land under grass there is a balance. The movement of water is equalized; there is an excess neither of percolation nor evaporation. Soil under grass is thus kept both moist and sweet, and useful natural clovers and vetches readily root in it. These plants have themselves a capacity for fertilizing the soil, but in general the whole of the grass cover adds to the soil's enrichment. For the grass is constantly growing, i.e. it is constantly using the energy of sunlight to collect inert elements and convert them into the organic phase; as it dies, all this mass of organic matter is added to the soil. Now this does not happen at intervals; it is going on all the time. A sward is a permanent fertility instrument, hence its importance.

More especially do the roots of the grass as they die form a thick mass of decaying organic enrichment, perfectly adapted to evoke the action of the soil bacteria and of the humbler species of soil fauna. The result is an abundant, teeming life in the top layers of any soil under a grass cover. Provided only that there is adequate air this life can be counted on to continue and to add month by month to the wealth of the soil. It is true that if the air is cut off this life dies down. This can happen when the grass gets old. Adequate aeration of the grass, therefore, is important; otherwise the result is a poor pasture in a sour condition.

These facts are now so well understood that a whole system of farming has arisen based on them. The point of departure is the fertility which the grass, acting as Nature's instrument, has collected; the aim is to catch this fertility at intervals and turn it to account. Land is kept under grass for three, four or five years, then ploughed up and used for cropping; the crop benefits by the fertility which the grass has collected. This can be done again and again. Such a system is known as ley farming, from ley, the old English word for a temporary grass field. The system is being much advocated at the present day (under the leadership of Sir George Stapledon and the staff of the Experimental Station, Aberystwyth).

It can be carried further and old permanent pastures can be ploughed up. But here we are faced with a dilemma. Either these permanent pastures have been properly handled, above all properly aerated and limed, in which case they are really too valuable to be so sacrificed, for they have been the work of years; or they have been neglected, have become sour, as we saw above, and pot-bound, in which case the fertility we gain by cashing in on them is not great. It would be better to improve such poor pasture and make the grass cover do its work properly before any attempt is made to turn it to further use. Grassland is so valuable, taken as the basis of an animal industry, that it requires to be treated with the utmost respect.

We may perhaps now pause for a moment to review the information which we have acquired on this subject of soil fertility and its gains and losses. We know that the tree is one great contributor to that fertility; it pulls up the valuable and needed minerals from the subsoil. We know that the animal is equally necessary; it is a donor of wastes. In the third place, we have realized what a useful agency we have in a grass sward, calculated as it is to keep the soil in good condition and to augment its content of organic matter; this, we have lately come to understand, can be easily brought about, that is to say, the process can be emphasized and accelerated, by ploughing up the grass and allowing it to decay rapidly in contact with abundant air and moisture.

This operation, apparently so simple, involves a great deal. We shall have to grasp a little more nearly what these questions of soil fertility imply. We have spoken of soil fertility in a broad way, but such fertility is the end result of movements and relationships which are among the most complicated in Nature; anything we attempt to enhance it is inevitably an intrusion into these relationships. This need not deter us as long as we never forget that they are still proceeding, as long as we remember that the soil is alive.

Much of this life of the soil depends on the circulation of nitrogen, which is the outstanding movement among many. This circulation is very wide, embracing the atmosphere and the plant as well as the soil. Plant, soil, and atmosphere are like cogwheels fitting into each other, supplying and exhausting the nitrogen in never-ending alternate motion. The movement is not always at the same rate; it is periodic, with the result that the accumulations of combined nitrogen in the soil follow marked phases, and these again differ according to place and climatic circumstances. The cultivator's aim must be to study this so-called nitrogen cycle very carefully in his own locality and to take the fullest advantage of it on behalf of his crops.

He has further to remember that the amount of combined nitrogen in the soil is in relation to the amount of carbon. The relation is 10 of carbon to 1 of nitrogen and is known as the carbon-nitrogen relation. It is the desire of Nature to keep this relation stable, and should it alter she at once sets to work to restore it. This means that any additions to the soil of organic matter (containing carbon) or of nitrogenous manures set up a whole series of fresh movements among the microflora, to whom is assigned the task of keeping the soil in condition.

With these facts in our mind it will easily be seen that the art of adding to the fertility of soils is not likely to be an easy one. From time to time in the history of agriculture new devices are tried, such as the device of ley farming just described. Ley farming is really only a special form of green-manuring, which has been known for a very long time as a means of increasing soil fertility. It is an old practice to dig in weeds and many nations, including those in the East, follow some form of green-manuring. A green-manure crop is one grown for consumption not by animals or man, but by the soil organisms; when the time comes to reap it, it is not carted away and harvested, but dug or ploughed in on the spot; the soil then digests it and anything it contains must augment soil fertility; the following crop profits. Green-manuring thus implies making a very special use of the green plant's capacity to collect and work up raw materials.

The results of green-manuring have been unequal and have caused much disappointment; the succeeding crop does not always prosper. The reasons are not difficult to understand. Green-manuring is based on the theory that any accumulation of nitrates in the soil must either be used or banked; if this is not done, they are in danger of leaching away by the action of the rain-water. The interposing of a green-manure crop is a form of banking; such a crop acts as a kind of savings account for the available combined nitrogen, which can later be released for the use of other plants. Success depends on a very accurate knowledge of the phases of the local nitrogen cycle, for unless the green-manure crop is interposed exactly at the right time, when there is an accumulation of combined nitrogen, it is more likely to exhaust the soil than to enrich it. A green-crop is a living crop and will act like all other living organisms; if its food materials are not ready to hand, it will look everywhere for them, in other words, it will comb the soil for any combined nitrogen it can find. The banking process can obviously only be carried out when there is something to bank, and any attempt to introduce it at the wrong moment naturally results in locking up the current account in a very disastrous way.

Another point which has to be realized is that the green-manure plant is at different stages according to age. When young it banks a great deal of nitrogen; when old, less nitrogen and more organic matter. If ploughed in young the material decays quickly, if ploughed in old much more slowly. Indeed, the amount of organic matter may then so far outweigh the available nitrogen that the soil organisms which have to carry out the decay have to call on some of the already existing soil nitrates to enable them to accomplish their work and get the carbon-nitrogen relation in the soil into balance again. When this happens it will easily be seen that the green-manure itself and the growing crop which is supposed to be profiting by it may be actual rivals for what combined nitrogen there is, so that instead of profiting by the green-manure the crop is starved of nitrogen. This accounts for many of the disappointments following on the use of a green-manure. When ploughing in such a crop the addition at the same time of a little animal manure or compost -- these will contain nitrates -- is by nature of a safety device to insure against such depredations of the existing soil nitrogen; it will be found that the green-manure crop then decays far more rapidly, for the organic matter which it includes has a sufficient supply of nitrogen assured to it; in this way an ample addition of all the elements that make for fertility is added to the soil in natural proportions.

It was supposed to be a very great improvement on ordinary green-manuring when it was discovered in the 1880's by Schulz-Lupitz that certain green-manures could be made to collect their own nitrogen; this nitrogen was the free nitrogen of the atmosphere. As we know, a certain group of plants, like the pea and the bean, bear on their roots, sometimes on their stems, small visible buttons, termed nodules; in these nodules are great colonies of microorganisms known as *Bacillus radicicola*, which have the unusual property of being able to fix, i.e. absorb the free nitrogen direct from the air and turn it into the combined form when the pea or bean haulm is dug in; this additional supply of combined nitrogen helps to increase soil fertility. The principle is again a sound one, but too much stress has been laid on it. The original experiments were made on very poor sandy soil in North Germany, and wherever comparable conditions obtain the results will be similar. But the work of the nodule-bearing plant is only one mechanism among several for transferring the free nitrogen of the atmosphere into the combined form in the soil. The eagerness with which the modern farmer has recourse to the help of such plants is largely due to the general running down of our European soils, which has rendered some means of restoring their nitrogen content essential.

The nodule-bearing plants are by no means so unique as they may seem. There are other agencies doing similar work. Indeed, soil which is really fertile will largely look after itself. This is well known to the best cultivators, those not caught by the prevailing idea that soil must always be whipped up for production; such cultivators will speak of making the land manure itself. In speaking thus they are relying on natural means of intensifying the nitrogen cycle, means which when once set into good motion will be almost automatic. For the soil is in no sense defenceless; it holds within itself or on its surface a sufficiency of the instruments likely to maintain its life at an appropriate level. It is true that if we wish greatly to intensify our cropping we have to do something to add to the fertility of our soils; these additions will themselves have to be of a type and kind to fit into the natural evolution of the soil; that is what is meant by manuring. But the intensification which we can thus procure is, as it were, only an extra story to a building which has been slowly constructed from the foundations upward and which awaited us already complete when we undertook our improvements. In fact, our most ingenious operations are but trifling additions to Nature's own sound management of her soils.

Our information on this point will probably be extended some day. It was only fifty years ago that we first obtained knowledge of the existence in the soil of large colonies of bacteria, which have been named *Azotobacter*, capable of fixing the free nitrogen of the atmosphere. These colonies are independent of the life of plants -- the technical term is free-living; several species are known and they are specialized for different climates. To their activities a great deal of importance may be attributed. Like all other inhabitants of the soil they are very sensitive to the conditions in which they live; it seems certain that only a sweet fertile soil offers them a good home. The result is obvious. A soil in really good heart will continue to keep up its supply of combined nitrogen owing to their presence: a poor soil which has to work without them will remain poor -- a singular illustration of the law that to the rich much will be given.

This is the explanation of much soil management, including grassland management. It is a fact known to every grazier that with a reasonable amount of care a good pasture will remain in condition for years. Many of our best pastures have long histories; they are the product of slow building up, but when once constituted they are stable and most valuable, which is one incidental reason against sacrificing them for any temporary ploughing-up campaign. They do, in fact, largely manure themselves, and they must do so partly by the presence of natural nodule-bearing plants like wild white clover but largely also with the help of the *Azotobacter* which they carry. Probably the best demonstration on these points was that made about a generation ago by one of our greatest agricultural leaders, whose ideas have recently attracted renewed attention. Elliot, the inventor of what is known as the Clifton Park system of farming, a system which has led to our modern ley farming practice, on acquiring some worn-out-grasslands in Roxburghshire in Scotland, set himself to reconstitute them. He ended his life by declaring that in his opinion these worn-out lands, which had been cropped for sixty and seventy years and never manured, could be made to produce grass as good or even better than they ever had. This was a definite effort to restore fertility which bad been lost, and in the absence of heavy manuring the only source from which the needed combined nitrogen can have been acquired must have been very gradually from the free nitrogen of the air by the action of *Azotobacter.*

What is significant is that the man who made this effort and was so sure of his opinion had been a coffee planter in Mysore and had already used his powers of observation in dealing with Eastern agriculture. He records an example of the way' the fertility problem was managed in that State in the growing of cereals; this example is striking because cereals are an exhausting crop. Six drills of cereals were sown and a seventh of beans, a nodule-forming plant. After the cereals had been reaped the spaces occupied by the six drills were ploughed up and the beans allowed to cover the ground and spread; the beans were then reaped. The only manure given was the stalks of the beans and a scanty supply of ashes from cow dung burnt as fuel. The nitrogen can only have been restored, partly by the nitrogen-fixing capacity of the bean nodules, partly by the similar capacity of the soil *Azotobacter.* This system had continued for many centuries. (R H. Elliot: *The Clifton Park System of Farming*, ed. Faber & Faber, p. 226 and p. 242.)

An even more significant example was recently found in North Africa. At Tafrata in Morocco pockets of land have been formed in the rifts of the desert floor. The depth of soil is twenty-five feet or more, the fertility inexhaustible. On this land lucerne is grown under irrigation and not less than sixteen cuttings are possible in the year. No animal manure is given, yet the manurial cycle does not fail. The observed fact was that there were no nodules on the roots of the lucerne, so that it cannot have been through these that the restoration of the combined soil nitrogen was made. It can only have been due to soil *Azotobacter*.

The ideas suggested in the above examples, taken at random, show an almost unsuspected capacity in soils to supply their own needs. There is always ample free nitrogen in the air; our problem has been to convey it as combined nitrogen to the plant. Hitherto we have trusted to manuring to keep up the soil content. It is possible we have been overlooking more direct ways of securing the same end, which play a much larger part in Nature than that with which we have been crediting them.

Nor have we even now finished our survey of what the soil can do for itself. One of the greatest puzzles of agriculture is the growing of rice. Not only is rice the largest crop in the world, feeding the most people, but it is also one of the most ancient; incidentally it is one of the healthiest -- very little disease is found. The strange thing is-and this is a fact too little regarded by the Western scientist -- that rice after the seedling stage is hardly ever manured. It is grown in the same paddy field year after year and this has been going on for centuries. That is an anomaly according to our ideas; we should have supposed nothing could be more exhausting to the soil. It is true that the seedling is highly manured; this makes it strong and resistant, for the earliest stages of plant life are like the earliest stages of animal life -- if the young organism is well fed it can later withstand much. But after being transplanted the rice plant has to draw all its nourishment from the muddy bottom of the paddy field, which never receives much enrichment, and has so continued for centuries.

The explanation must be that these fields have manured themselves. By some means they must have restored their own nitrogen content; otherwise growth could not conceivably continue. It is a legitimate supposition that the rich algal film which always occurs in the paddy water long before the rice harvest is the nitrogen-catching agency; like the *Azotobacter* the algae have this capacity for nitrogen absorption. The nitrogen they trap is presumably added to the soil each succeeding season. The algal film, the action of which must be intense, is a good deal more marked in tropical zones than in our own. Here then we have a perfect example of fields which manure themselves. The scale on which this happens and the uninterrupted continuity of the process are instructive lessons in the possibilities within the reach of mankind.

The gains and losses in soil fertility following on man's opening up of the earth's surface is a study which can convey many lessons and some warnings. One likelihood which emerges is the risk of a long slow soil deterioration. In view of the demands we put on the land, of what we expect our plantations, fields, orchards, and gardens to do for us, this is not surprising. The strength of our soils is nevertheless so great that deterioration is almost imperceptible; no one generation of men and women is immediately conscious of what is happening; the earth seems always to give forth, the green carpet renews itself.

Nor is this gradual deterioration imperative; it is not a law of Nature. It can be prevented. It is worth while to contrast the history of different agricultures and different civilizations. One or two nations have solved the problem of maintaining fertility; one of the greatest crops in the world has been grown for centuries without detriment to the soil; the densest population to be found anywhere continues to subsist and to carry on a famous art and culture without injury to Mother Earth. When it comes to our own problem we find ourselves in possession of a great natural asset -- our grasslands. How are these to be treated? Two facts emerge. First, that the animal and the grass it eats are one project and together contribute to the wealth of the soil; second, that the grass and the soil are also one project; if the soil renders the grass thick and good, the grass in its turn enriches the soil. In fact all is geared together, the gases of the air included.

That is why it is so necessary never to relax our hold on soil fertility, because here the start is made and from this base everything is affected. We shall do well, therefore, to study the origin of soil fertility, to trace it to its actual beginning, to describe that section in the Wheel of Life where it first emerges, in fact, to follow the turning of the Wheel to its lowest revolution. In doing this, we shall find that we have again to take up the lesson of the East.

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The Earth's Green Carpet

By Louise E. Howard

Chapter 7
The Lowest Revolution of the Wheel

In our preceding chapter we noted that in Western farming the European system took pride of place, thus based on it European culture had remained in being for two thousand years or more, and that in spite of frequent phases of severe soil exhaustion natural law had so far been obeyed that the cultivated areas of Europe remain capable of complete restoration at any moment. The prevailing practice which has made this possible is the pursuit of mixed farming, the principles of which are well understood by the European peoples, These principles, already worked out into an ingenious management of rotations and of mixed grazing, have during the last fifty or sixty years been somewhat strengthened by some newer devices calculated to add as much green organic matter to the soil as is obtainable. In some cases success is registered; it has been found not altogether impossible to get fields into a good state of fertility under a grass cover and to maintain them in that condition. But the picture is not a stable one. It is not the picture of China. Something is lacking; there is a note of uncertainty. What is wrong? Why do we have to face, even now with all our knowledge, that terrible danger of the slow running down of soil fertility which we should have left behind us with the passing of the centuries?

The answer when we come to it is extraordinarily simple. We have not yet grasped in its entirety the first law of Nature, the law of mixed existences, that supreme tenet which seems to run through every phase of life on this planet from first to last. In so far as we have applied this law we are on safe ground; but we remain consistently unaware of our failure to carry it to its final terrific conclusion.

Our general use of the animal as our farming partner is an act of obedience to the law. Moreover our use fastens on the animal in its important aspect-we highly value its waste products; these, as we know, are an essential I part of the fertility cycle. Where we fail is in ceasing to follow the working of the law in that section of the turning Wheel of Life which comes after these waste products have been accumulated.

We must now go somewhat thoroughly into actual methods for the use of wastes. Simply to declare that they must be returned to the soil is not enough; we need to probe further. We need to know when and in what way and by what agents such animal wastes, or any wastes, are to be re-incorporated into the soil. Our present chapter will be devoted to this problem.

To say that European agriculture is based on the manure heap is to say a great deal and yet not enough. What is the manure heap? An evil-smelling, sodden, fly-ridden midden, of which the best components seep away as wasted liquid into the nearest ditch or escape as strong ammonia into the air; the remaining matter putrefies rather than decays. Yet thus we meet it as far back as we can trace European husbandry and thus it has continued ever since. Its origin is not known. Probably the dung was looked on as so precious that it was collected in order to establish ownership; we do know that under the manorial system it was the prerogative of the lord of the manor. There was a good deal less of it than was needed, because it was exceedingly difficult to keep animals alive during the winter, a difficulty not overcome until the introduction of root crops in the eighteenth century. When that difficulty had been surmounted, the manure heap was established on every farm.

How does Nature manage this business of the disposal of waste? In a very different manner. The animal's habit of roaming scatters its waste products widely. Exceptions are most rare; where they do occur, as in the accumulation of guano on isolated sea rocks, vegetation is absent -- the earth's green carpet falls to appear. This is illuminating. Leaving aside these isolated exceptions we cannot but observe that the law about the interlocking of vegetable and animal existence continues throughout the turning of the Wheel. It does not suddenly cease but *remains in force as potently during all the processes of decay as during those of increase and growth.* The animal products mingle with the vegetable waste -- which themselves fall and drift and are distributed everywhere there is no attempt at separation, no isolation or distinction, just a scattered deposit, leading to an inevitable mingling, a combined decay. Even the dead bodies of the animal world obey this incontrovertible principle; they remain on the floor of the forest or prairie and are at once in immediate contact with the vegetable and microbial life around them -- they mingle with the dust. At no point whatsoever can we find any segregation of the two worlds, the plant and the beast; they are conjoined in life; they unite in death.

The scattering of wild wastes over the surface of the earth is Nature's way of insuring that her law continues in operation to the end; it secures, during the stages of their decay, the mingling of animal and vegetable matter together with access to the needed air and water. But the ordinary manure heap is not, except at its outer edges, accessible to the oxygen of the atmosphere; the heavy manure packs closely and the heap is airless; nor is it, except at its extreme base, in contact with the earth; finally, it is not mixed with sufficient vegetable matter. Thus in three ways it contradicts the law which decrees mixture and forbids separation: it corresponds with nothing in Nature. Is it surprising that it ends as a nuisance, something from which we instinctively recoil, which we come to value only because a long experience has told us that in spite of all it is essential to our continued existence?

Why did we not take a lesson from what was before our eyes? As if to drive it home to us Nature has visibly emphasized the effect of the ordinary cowpat, where, for a time, a shortage of air, an excess of animal manure and a deficiency of vegetable matter come together. Every farmer knows that the grass immediately round a cowpat is rank and dark green; it is heavily overmanured with nitrogen. Such is the effect of this small-scale concentration of too much animal waste. Such grass is avoided by the grazing animal; there is something unpalatable in this rank growth; horses are specially particular and will not feed off that part of the field which has been stained, as it is called, by their droppings. The effects are of course corrected by Nature. The rank growth is only the first stage; she can afford to take her time about completing the other stages. The delay does not incommode her, because in wild life there is ample room and the grazing animal will have sought fresh food miles away. The confinement of the domestic beast draws our attention to its distaste; its instinct is to avoid what has not yet achieved that perfect harmony, that balance of the vegetable and animal elements which is so deeply characteristic of the green carpet's continuance. (There is probably also a strong instinct to avoid the danger of picking up parasitic worms passed through in the droppings. Harrowing or even ploughing up may have to be resorted to in order to cure very bad stain.) This simple observation might have helped us to understand the right treatment of animal waste.

There is another point about the manure heap which we overlook with far too much nonchalance -- the escape of ammonia into the air; this was mentioned above as characteristic of the ordinary midden, especially when freshly made up. Now this means a serious loss of combined nitrogen and is the exact opposite of what is wanted, for, as we know, there is always a fight for such nitrogen going on in the soil. It is not only the exact opposite of what is wanted, it is the exact opposite of what Nature does; for Nature has so arranged matters as to balance nitrogen so that it is not lost from the soil to the atmosphere, but is actually gained from the atmosphere. We have already examined the way in which this is done by means of certain types of vegetation and the *Azotobacter*.

If the plant then can catch at the atmospheric nitrogen and if we can use this its capacity to maintain the fertility of our fields, how absurd, is it not, to lose on the swings what we have gained on the roundabouts? How absurd is it for us to reverse the rule of Nature, to allow our reserves of nitrogen from the animal excrement we have painfully collected to escape instead of doing our best to add to it! The manure heap is proved to be indeed deficient. Useful as it has been, because in the long run it does to some extent maintain the law of the return of all wastes to the land, because it does join the animal to the vegetable world, yet it could scarcely be more faulty in its details. It is to be regretted that our European ancestors, misled perhaps by the criterion of the ultimate value of the animal matter, should have clung so tenaciously to the building up of the manure heap. It is one of the few points on which we may definitely say that European practice has failed of the mark, for in general it has been a fine tradition.

What then must we substitute for the manure heap? It is not the act of accumulation of valuable material which is wrong, it is the conditions under which that accumulation is allowed to degenerate and fail of its fulfilment. *If we intensify the processes of growth we must also intensify the process of decay;* and we must do so in the same degree and with the like eagerness. For it is the aim of all agriculture to intensify the processes of increase, but it has been the cardinal mistake of Western agriculture to pay far too little attention to the processes of decay; we have contemplated only one-half of the turning of the Wheel. The other half, the hidden half that turns away from our sight, is as important; the Wheel can never come full circle unless we see to it that this is accomplished in all its perfection.

Once more we reach the position that our only salvation is to be found in a frank imitation of natural processes; once more we shall do well to refer to the floor of the forest. We cannot do better than do what the Chinese do -- as it were, roll up that rich carpet into convenient concentrated masses: we cannot do better than constitute our wastes into compost heaps.

The principles underlying composting indicate something more fundamental than a merely useful improvement in farming practice; they are the re-assertion of that supreme Law of Nature, the law of mixed existences, to which we have already paid such frequent tribute. They insure in a way which is otherwise absent the required mixing of the animal with the vegetable element, combined with such access to earth, air and moisture as together reproduce with exactness the conditions under which Nature chooses that wastes should ordinarily decay.

The compost heap is composed of an intimate mixture of three to four parts by volume of vegetable to one of animal wastes mixed with a little earth, the whole being built up to a height of about five feet; a thin sprinkling of the earth to lie on top. (Or wood ashes; the purpose in either case is to neutralize excessive acidity. The floor of the forest is usually somewhat acid; forest growth likes a sub-acid soil.) The material may be built up in an earthen pit, in a mass (the "heap" proper), or in a box constructed of rough timber open to the air above and to the earth below and with half-inch interstices between the side boards to insure the further entry of air. The material thus layered or mixed must be moistened though never soddened, the conditions in the forest being so far imitated that this moisture is supplied in a gentle sprinkling or spraying by hose or can in the same way as the natural downpour is broken up into a gentle patter by the leaf canopy of the trees. Shelter too from extreme cold or violent wind is to be given, for the forest provides a very noticeable degree of shelter; in our climate we can do this by siting against a hedge or south wall or in some other protected corner.

Above all there must be air. The fallen wastes in the forest are kept very loose by Nature. As they sink they compact gradually, but for at least a few inches there is abundant air. This is the secret also of composting. Air is the first essential; without it there can be neither start nor continuation, for the whole beneficial processes of decay depend on an ample supply of oxygen to enable the fungi and bacteria to do their work. To insure air in the compost heap is not difficult. If left as described the heap breathes from above and below and also at the sides; it must, of course, not be trampled on nor pressed down. To add to the access of air from the bottom a thin layer of twigs or branch material will lift the heap a little (in large heaps brick air-channels are sometimes supplied for this purpose) and will itself decay and add to the value of the compost; the twig and branch fall is included in the natural forest waste and any composting which continues to omit this material becomes in course of time deficient both in potash and in the lignified cellulose essential for the best compost.

A properly made compost heap heats up rapidly. The degree of heat is surprising (in a well-made heap 150 deg. F., sinking to 90 deg. F. at the end of ninety days) and should develop in from three to six days according to circumstances; the type of material used can help, a proportion of grass cuttings and fresh green stuff, for instance, helps the heap to heat quickly. Very often, when a fork is thrust into the heap at this stage and the heap is a little opened up, it will steam visually to the eye. The operator may then be happy, for his heap is going with a bound. He may be happy also if he sees rich threads of grey fungous matter clinging to and clothing the material in the heap, especially the small woody boughs and branches. This rapid growth of fungous *mycelium* indicates that Nature is at work with a will. The fungi are busy eating up the mixed material. Such fungi are the real workers. They are Nature's chemists, her bench operators, her mechanics, her skilled technologists. In making a compost heap we do no work; what we do is to provide conditions. Warmth and abundance of air are essential and we may have to take some trouble to secure these. (For small heaps warmth is secured by making in a box as described above in the text; this idea comes from New Zealand; large heaps, having less evaporating surface, protect themselves. For details of the box, see Appendix A.)

There are tests of the correctness of our conditions. It is as well to realize that Nature has provided herself with a certain choice in this matter of the removal of wastes. The normal -- what we may perhaps a little incorrectly call the healthy -- process is that of fermentation, i.e. of combination with the oxygen of the air to form beneficial products: there is a kind of slow burning up which has much of the purificatory effect of fire. But if abundant oxygen is not present, then quite a different set of processes may be initiated, those of putrefaction. These are accompanied by smells and other effects highly distasteful to us. Our instinct on this point is powerful and seems to be one of those rare instincts which civilization has not damaged. A compost heap should never putrefy; in this it is greatly superior to the manure heap, which easily putrefies. It should never breed maggots or flies: it should never emit an unpleasant smell. These are infallible signs of faulty conditions and need to be corrected without further delay. (The cause is usually excessive wetness or some other form of imperfect aeration. The cure is to re-admit air by a turning; the evil then disappears. With a very little practice it never occurs.)

As he watches, the compost-maker will see his heap sink: the sinking is quite noticeable. Again this repeats what happens on the floor of the forest. We noted above how loose were the forest wastes for a few inches, but that below this depth they compacted and formed a close mass. Exactly the same process takes place in the well-made compost heap. When the intense oxygenation -- the slow burning up process -- has been finished, another stage succeeds: what the scientist calls the anaerobic stage as contrasted with the previous aerobic stage. The air begins to be cut off; the fungi are succeeded by bacteria, which now take over the final operations. The dead bodies of the fungi and bacteria and the undecomposed portions of the vegetable and animal residues amalgamate to form humus; the compost matures and ripens. In a surprisingly short space of time -- twelve weeks -- all processes are complete.

Much has happened during these few weeks. In truth, the chemistry and biology of the compost heap is not a little complicated. The organisms taking charge change rapidly, nor are their various types and kinds always present in like proportions in all heaps; there is no hard and fast prescription as to the components of a heap: the fungi and bacteria jostle and fight each other, the organic chemical compounds which emerge are of wide range. No heap is ever static; it is not the same to-day as it was yesterday, and will change again to-morrow. In truth, the compost heap is alive: it is just a convenient name for a vast mass of living organisms which have their habitat, and live out their life cycle, in any mass of humus, whether accumulated in a mound or spread out as the topsoil of field or forest. Compost is naturally teeming with life just as the soil is teeming with life.

Compost properly made should be a quality product. It should emerge as a rich, crumbly, dark, sweet-smelling material, easy to handle and packed with the life-necessities of living things. It should have the power of fixing the nitrogen of the air which is the mark of the fertile earth. (This undoubtedly takes place in the well-made heap. The proved figures vary according to conditions and very much according to the materials used in making the heap. Details of a number of careful and exact tests in Howard: *The Waste Products of Agriculture: their Utilization as Humus*, pp. 100 *sqq*. If the heap is kept too long the capacity to fix nitrogen is presumably lost. It is therefore best to use the compost soon after ripening.) In truth it should be the same as what the forest manufactures; it should rank with Nature's finest efforts. For this has been our aim all along, and unless it is attained we have strayed from the path.

In the details just given we have a description of one well-known composting method (the Indore Process; see Appendix A). The choice of material, the minutiae of management, the scale of operation are scarcely the important things, though they make for success or failure in practice. What we need to stress for our present purpose are the underlying truths. What is it that constitutes the process of composting? What makes it so valuable? Why must we go to all this trouble?

In the first place, in making compost we are adding to the humus supply of our topsoils, those precious few inches of earth which are the very hinge of life on this planet, which at the outset we referred to as Nature's most pre-eminent reserve. Humus is a Latin word meaning soil, but in science its significance is a little narrowed to indicate that part of the soil spread over the surface of the earth which is the end product of the decaying fragments of organic matter deposited at all times and in all places by the life and death processes of plants and animals; this mass of fragments is further the habitat of millions of unseen organisms and also of invertebrates like earthworms, who, using it both as a home and a food supply, radically transform and shape it. The final material is therefore varied, how varied we hardly yet know in spite of much investigation. It has been described as a skin to our planet and the description is very apt; to strip it away is just as harmful as would be the stripping of the skin off a living animal. Compost may be called man's contribution to this protective skin. If, so to say, he scrapes a little off the skin when he cultivates, he hastens to put it back again by composting.

But composting does more than merely maintain Nature's great insurance system of reserves; it intensifies. Herein lies its value to us. From the practical point of view it adds, in the first place, volume; a compost heap, by the admixture of vegetable waste, turns the whole mass into fertilizing material, thus multiplying our available, often scanty, supplies of manure three or four times over. Composting further hastens the work of decay. The process is in truth nothing whatever but a speeding up of all that happens on the floor of the forest; we do in three months what Nature does at her leisure. She accumulates for centuries and need not hurry. Our smaller supplies of humus are quickly used and it is an advantage to be able to remake them again and again. Our turnover is thus repeated at short intervals, but without loss or damage or despoiling of the capital wealth held in our topsoils.

Now this is a parallel to what we are doing in our crop-growing: we are always speeding up Nature. We are entitled to do so; we could not feed ourselves unless we had that much power. Surely it is obvious that if we do this when we grow our crops, we should also see to it that an action of comparable rapidity goes on where the Wheel of Life turns away from us unseen? We must give to Mother Earth as quickly as we take from her, and in no less ample measure.

Nor is it a small advantage that we -- or rather the Chinese -- have hit on the idea of making our compost as a process separate from our crop-growing. This is not an essential point of principle, but is a great convenience. Composting can also be carried out over the surface of the field. Animal manure or some already prepared compost) can be lightly ploughed in with the stubble or some green-crop. (Not too deeply, or the air is cut off. The process is greatly superior to ordinary green-manuring and should replace it.) If done while the earth is still warm in the late summer the results are highly successful. This is known as sheet-composting because done in a sheet over the whole field. In many ways sheet-composting is an even closer imitation of natural law than the making of compost in a heap. It is extremely practical and convenient and has the advantage of saving labour; the material need not be gathered together and need not be redistributed. It should have a big future in farming, but it sacrifices the speeding up of the processes of decay which is such a feature of the compost heap: it can only take place between the growing of crops and, as already stated, at a suitable season of the year. It can be neither a very quick nor a continuous process, though, in regard to the first point, the time required in the case of a truly fertile soil is surprisingly short. Nevertheless, it cannot be contemporaneous with the growing of crops. (It can obviously be contemporaneous with the growing of grass; the well-known Hosier system of moving dairy cattle systematically over a field implies a form of sheet-composting; the vegetable and animal wastes are combined. The ploughing or digging in of such combined wastes in pits between bushes or fruit trees is another adaptation; this has been very successfully carried out in tea-gardens; it might be described as "pit-composting".)

Perhaps we are now in a position to realize some of the far-reaching implications in the correct disposal of wastes. We shall treat our soil for what it is -- a living thing. Like all other living things, unless it is supplied with what it needs, it dies. For our own survival it is vital to give right treatment to that precious skin of humus which Nature has so wisely laid over the bare earth. To observe its condition and to maintain it fertile should always be the first consideration in our farming and no cultivation should be considered allowable which does not conform to this fundamental requirement.

We shall not be surprised at anything which correct methods can achieve. The results of any system of composting are indeed remarkable. Of their ultimate nature we shall treat in our last chapter, only the straightforward effects will be dealt with here. These are easily recognized -- they usually appear quickly, but it is not to be supposed that worn-out land can at once be brought up to a high state of fertility. Some little time must pass, perhaps three to five years will be needed, though long before the completion of this period improvement will be visible. But when once regularly composted the signs of a fertile soil are unmistakable. Nature paints them into the landscape, for her pleasure and for ours.

There is an immensely improved appearance. This is always revealed when a well-composted field or garden is looked at as a whole; the mass of leaves and flowers seem to stand out by reason of their fine colour. Colour is not a quality which can be expressed in statistics. It is of importance to the commercial producer and adds to the pleasure of the amateur grower of flowers. The deep and beautiful colour which follows on the use of compost is not, however, confined to the blossom only. A composted lawn will lose its grey washed-out appearance, and the field crops will stand out in great sweeps of emerald green. Moreover, a close examination will reveal that something more than colour is present. Stems are far more vigorous, thicker, better formed and ribbed and height is sometimes considerably increased. Above all the stance of the plant is noticeably superior, a quality which is carried into each separate leaf, which is set at a better angle to catch the sunlight and stands out more. It is the aggregation of these characters taken in the mass that creates the look of beauty so noticeable from a distance.

We have more than appearance to reward us: there is the asset of larger amounts of crop. Increases in harvests from composted crops are definite. Returns may be raised by thirty, forty, fifty or even one hundred per cent. Such increases in yield have been recorded for very different crops in different parts of the world, for tea in Bengal, potatoes in New Zealand, coconuts in the Federated Malay States. The increase may come from the prolongation of the life of a fruit-bearing tree or bush. Thus the coconut trees of which the record is made had been beyond the age when any appreciable response was expected; they not only survived to bear a better harvest than before but "looked like even doing better". The profitability of compost arises partly in this way, from the generally superior state of the plant treated, its better endurance, its longer life. Amounts of actual harvests go up slowly, but are usually dependable. (Potatoes in the Greytown district of New Zealand were harvested to an amount of 18.87 tons per acre from composted land as against 10.33 tons per acre from uncomposted land (1941-2); *Compost News Letter*, No. 5, pp. 15-16; at the Permatang Estate, Banting, composting raised the yield of copra from 9 piculs to 14 piculs per acre averaged over five years; ibid., No. 2, p. 2. There are any number of examples.)

Of further qualities we may note fine flavour and keeping power. These are aspects of good health, the consideration of which is so important that it requires separate discussion; the reader will find this topic treated at length in the last chapter of the present book. He will there find the significant claim made on behalf of composted crops that they display a health and stamina which crops cultivated on other methods cannot approach.

It is certain that composted crops resist frost well. In addition, they both come into fruition earlier -- in the gardener's phrase, they get away rapidly -- and stay in bearing longer. Not only is this true of a particular crop but it also applies to the succession of crops; an experienced market gardener has stated that any cost of composting is amply repaid because an extra crop a year can be got off the ground; in course of time two extra crops, namely, six in place of four. That the bearing life of permanent plants and trees is prolonged was shown in the case of the coconut palms mentioned above. Bloom lasts longer, fruit does not drop, it matures well; in every way the plant shows itself able to stand up to any conditions which it may have to face.

But it is the state of the soil which should in reality draw our attention. On composted soil many paeans of praise are sung. It "hangs loose", it is "crumbly", "easily workable", it "never cakes", is "not sour", it "looks good and smells better", it protects the plant roots from the fierce action of the sun, it holds moisture. The last quality is most important and is supremely evident; it is invariably commented upon and it is, in fact, conceded by all. Humidity is necessary to plants at each stage of their growth; it swells the seed, opens the bud, sets the blossom, and ripens the harvest. The moisture-holding capacity of composted soil has to be seen to be believed. In such soil, rich in organic matter, the moisture actually penetrates the soft large compound particles themselves -- there is a series of minature sponges to receive it and hold it; in soils lacking organic matter there is an unfriendly mass of hard minute sandy grains; the water cannot get into these, is forced into the channels between them, seeps away unused with a rapidity most disappointing to the cultivator, whereas 'the humus-fed soil holds water for days after a shower. (R.H. Elliot, *Clifton Park System of Farming*, ed. Faber & Faber, p. 232, quotes a statement that three years' experiments with farmyard manure enriching the soil with organic matter showed that the first foot of soil contained 18-3/4 tons more water per acre than adjacent and similar but unmanured land, the second foot 9.28 tons and the third 6.38, the three feet together 34.41 tons.)

It is unnecessary to continue the catalogue of these qualities. No cultivator who has once followed the indications of Nature and read her wise lesson from the floor of the forest has ever had cause to turn back. He may have begun in doubt; he ends in enthusiasm. He may have argued and queried, cried, out at the work to be done; before long he is calling on all and sundry to join him in an eager campaign. He may have urged that he had nothing wherewith to fill his pits or build his heaps, and in truth he can find little verdure on his starved land; he ends by cutting great swathes of herbage from forgotten corners of his fields and gardens whither the general richness has spread. So eager has he become in his passion to give back to the kindly soil as well as to take from it, so finally has he learned from Nature's deep and far-flung generosity, that he will set aside acres to grow special crops -- true harvests -- for the sole purpose of adding to his great mounds of waste. If only once man can understand the law which bids him in his use of the green carpet to look on himself as a borrower, who, having had his profit and enjoyment on easy terms, is glad and ready when the time comes to repay his just debt, he will not only be conferring on his fellow-creatures material benefits in the shape of the good and wholesome food which he produces, but will have done his share in asserting truths which are of their very nature part of a philosophy of human life.

The soil out of which the green carpet springs is the lowest revolution of the Wheel. Beyond this we cannot trace what is essential to life and may look on the slow processes of geological change in subsoil and rock as action preliminary to the build-up of the living cover. This great mantle of live sweet earth is the beginning of all: it is the start of life. Here the Wheel turns finally and having borne downwards to its nadir again begins its upward spin.

We have but one more link to trace: to consider what are the arrangements which Nature contemplates for making available this mass of material which she has been at such pains to evoke out of the changes from decay into life. How does she operate this collected wealth? How does she place it at the disposal of the green leaf? It was with the work of the green leaf that we began our investigation and if we can point to this last link in the long chain, we shall have completed our outline of the natural round.

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The Earth's Green Carpet

By Louise E. Howard

Chapter 8
Final Preparation of the Soil

Broadly speaking there are four paramount reserves in Nature -- the atmosphere, the waters, the rocks, and the soil. We have just been reasserting yet once again that it is in the soil humus that Nature's reserves begin to pass into the active round; it is here that the chain of living has it start. Here the principle of accumulation gives way to Nature's decision to take her minerals into use; she begins to call on them in a very special way. First comes the microbial and bacteriological life of the soil; from this proceeds the manufacture of the materials needed by the plant; these are conveyed into the plant and then by means of sunlight and the green leaf converted into food; this nourishment passes in due course into the bodies of animals and finally of man. At every point in this upward swing there should be an easy passage, ensuring the smooth transference of new materials and of reserves from one type of organism to the next.

For the initial principle of accumulation is not in any way set aside. Everywhere along the living chain will be found storage of useful elements specially placed at points of danger to guard the organism from shock, strain, or disaster. Every plant, every animal including ourselves carry within their structure or bodies such banks of reserve material. Life is far too great a thing to be carelessly handled, and though we commonly say that Nature is indifferent in the extreme to life and callous in her indifference, she cannot be accused of failing to supply each of her creatures with abundant means of protecting itself, if it is in any way fitted to do so.

To carry out this system Nature has devised most careful methods, nowhere better exemplified than in the way she sets about her first great task of bringing her store of humus into action. For her purpose throughout is not idleness but activity. It is an interesting fact that the humus in the soil does not increase indefinitely: this reserve is not accumulated in order to be hoarded: what is made is also to be used. In undisturbed forest or prairie the depth of fertile soil may be considerable, as we have seen; but this accumulation is no mass of inert matter; it is not a banker's lock-up investment but a true working capital in constant circulation.

Of the four paramount reserves of Nature the soil is the only one over which we have such mastery as may amount to a dominion. Our use of the atmosphere, waters and rocks can only be temporary and incidental. But it is our destiny to interfere in a fundamental way with the surface of the earth, which is our habitat and on which we have been placed. This fate of ours puts into our hands power of a peculiar kind, for as well as utilizing rightly we can also injure. To avoid this disaster we have everything to learn from the closest observation of natural methods. More especially is it advisable to do so at the outset, in our initial treatment of the humus reserve. Provided we get this treatment right, our liberty of action at the later stages of production may be considerable.

How does Nature put her humus into action, how does she cultivate and energize the soil? For cultivate it she does in a very definite and deliberate way; this is her first step in the upward movement. With that cultivation she closely links processes of transmutation of the soil contents; her mechanics, her chemistry, her biology all run together. In choosing some part of these processes to describe, we do not pretend to exhaust the subject. But certain steps in her treatment of the humus reserve have recently been emphasized among us or have for the first time attracted the notice which they merit. These examples of her working methods we may discuss with advantage and from them draw our definite conclusions.

First, her cultivation, drainage and aeration. This work is done by means of agents of many types and kinds. We need not refer again to the piercing and combing action of her vegetable partners, the trees and plants. As we know, their larger roots can shatter rocks, while the pulverization of the topsoil resulting from the spread in all directions of a network of the fine root-systems of some of the lesser plants has to be seen to be believed; it rivals the results of the most delicate machinery. But tree and plant roots are by no means the only instruments employed. The soil is worked and moved and changed about by animals also, especially by those smaller animals whose normal habitat is on the surface or just below the surface of the earth. These are Nature's willing army of diggers and of hoers, her ploughmen and her carters, endowed like ourselves with the ability of motion and in that respect endowed with the greater capacity and power.

These more mobile agents of Nature are indeed very efficient. They are million-handed and myriad-footed and make our own coarser farming instruments look clumsy and ridiculous. They are the ants and termites, the beetles and insects, the grubs and larvae, the worms and slugs and snakes and lizards. They are also such animals as the mice and rats, the rabbits, badgers, moles, in fact, all the burrowing animals, large and small alike. Some of these agents are familiar. Most of us know that the mole in the course of his burrowings throws up mounds of finely pulverized soil which form the materials for a perfect mineral top-dressing. His efforts are rather of the violent kind and may be disturbing to the roots of growing crops, so that he is often pursued and killed by the farmer; but he is a natural soil digger, all the same, and we could ill afford to do without him. The same may be said of the wireworm, on whom so much abuse is lavished. His function is to cut through the matted roots of worn-out sour decaying turf and prepare them for Nature's composting. That is why when such wornout turf is disturbed and a crop like wheat immediately planted, he is -- to our mind -- so destructive; he has been robbed of his proper task and naturally eats what he can, namely, our badly grown wheat. If we are wise we do not let our grassland get into such a state as to invite the wireworm, or, if it has, we allow time for re-adjustment; after an interval we shall find that Nature, not needing the wireworm any longer, has quietly removed him; it is not part of her design to keep workers idle on the dole. These simple examples will introduce our principle, which is that throughout the turning of the Wheel there is placed exactly that kind and type of working agent which is required at each point.

Of Nature's varied army of cultivators and diggers we shall choose the earthworm for our attention. Not only is this creature beyond question one of the most important of Nature's agents, but its work is such that it can easily be followed in our climate. Were we situated in a tropical zone we should choose the termite, whose operations are equally ubiquitous and very similar.

The role of the earthworm is varied. In the first place, the earthworms provide a ventilating system by means of their tunnels; through these the soil draws in oxygen and nitrogen and expels the air it has used up. Surplus rainfall also drains away. The earthworm population truly plough and drain the ground and have been well named the cultivator's unpaid labour force. The work done by the earthworm as digger and cultivator was wonderfully investigated by Charles Darwin, whose book on *The Formation of Vegetable Mould through the Action of Worms and other Invertebrates with Observations on their Habits*, the last he wrote, was published in 1881. He showed conclusively the colossal power of these lowly creatures, how they are always at work raising the surface of the earth by bringing up the lower layers of the soil and strewing them on top. Though completely deaf, nearly blind and with feeble smell, for their size they have great muscular power. They are indefatigable and so immense is the cumulative effect of their labours that they gradually cover great monuments. It was the first explanation ever given of the well-known phenomenon of the sinking of stones and buildings. (The general character of what the earthworm does, both in digging and aerating powers and its manurial value, was known to Gilbert White, in whose *History of Selborne*, first appearing in 1789, there is an interesting short passage on this creature. [Letter No. XXXV, 20 May 1777, to the Hon. Daines Barrington.])

An earthworm lives about ten years, not longer. A considerable proportion of the earthworm population therefore dies each year. Their bodies are added to the animal organic matter in the soil. Only rough calculations have as yet been made of the amount and value of this animal element; it must be considerable. From this point of view alone the maintenance of a prolific earthworm population is important; in death as in life the earthworm helps to build the soil. It is therefore no small matter to note that the earthworm, ubiquitous and prolific though it be, cannot survive every condition; like other living things it ceases to exist where its habitat is interfered with or its food supply destroyed. Where there is no humus the earthworm is not found; the natural agent and its natural environment are inextricably conjoined, and a loss of humus means the retreat of the earthworm. That is why the presence of a good lobworm, as thick as his little finger, in every spadeful of earth which he turns up is so pleasing to the gardener; when he sees this creature in abundance he knows that all is well with his soil. No further tests are needed; the earthworm, Nature's broadcaster, will tell him all he wants to know.

But earthworms do a great deal more than aerate and drain the soil or add to its crude organic content. Wonderful as is their mechanical work when living and important as is the continuous addition of animal matter won out of their dead bodies, this does not exhaust their usefulness. They actually eat and digest the soil and in doing so add enormously to its fertility. Their casts, manufactured in their alimentary canals from dead vegetable matter and particles of soil, are thrown up on the surface in hugh quantities; when the land is in very good heart the total of casts, in and above ground, may exceed twenty-five tons to the acre in the course of a year. Having been acted on by the earthworm's three pairs of calciferous glands these casts emerge in the first place very finely ground; having been neutralized by constant additions of carbonate of lime in their passage they have a heavy calcium content; having been saturated with the intestinal and urinary secretions of the earthworms they are exceedingly rich in certain nutrients. American investigators have shown these casts to be five times richer in available nitrogen, seven times richer in available phosphates, and eleven times richer in available potash than the upper six inches of soil. The earthworm is not only the gardener's ploughman, he is the gardener's manure factory.

If the roots of a potato are followed downwards, they will be found to be making full use of the earthworm tunnels. Where a fresh wormcast has been deposited inside the tunnel, a new web-like net of roots may be developed penetrating the deposit in all directions; only when this has been accomplished does the root pass on. Obviously there is something in the deposit which the root desires, which is of great value to it, which it pauses to absorb, something which renders the earthworm's cast more welcome to the plant than untreated soil. Thus these humble creatures are made welcome and encouraged, the plant will have supplies of material from which it can build up the life it needs.

Long before man existed the land was regularly ploughed and manured and still continues to be thus ploughed and manured by the earthworm. "It may be doubted", says Darwin, "whether there are many other animals which have played so important a part in the history of the world as have these lowly organized creatures." It is a marvellous reflection, he adds, that the whole superficial bed of soil is brought to the surface through their bodies every few years. We may agree that what they do is indeed important and that we have every inducement to provide the conditions which favour their existence.

One of the points of interest in studying the earthworm is the way in which it unites physical with biological and chemical action. If generously handled our earthworm friends will at the same time aerate and drain the soil for us and will also handle our manurial problems, especially the phosphate and potash problems in which their contribution is of special importance. This comprehensive action is in accordance with what happens to be a general rule in Nature's preparation of the soil; it is hardly possible to distinguish very rigidly between physical and biological soil effects, they seem so closely interwoven. Again and again we find the one involves the other; if the soil is injured physically it suffers in its biological content; if it is biologically starved it collapses physically. The soil microbial population, for instance, change the soil content chemically and biologically, but also glue the compound soil particles together.

Nevertheless, there appears to be a stage when Nature, satisfied with her physical treatment of the soil, proceeds to concentrate on her biological operations; she *energizes* the soil. For soil, to be effective, to be the medium from which the earth's green carpet can arise, must be alive. Nature does not care to work on a sterile soil, not even very greatly on her own deserts. These sands sometimes contain enormous stores of mineral wealth, but Nature does not trouble to draw these into her moving Wheel unless some chance accident starts up the life-round; the occurrence of moisture in the scattered oases shows what fertility lies dormant. Elsewhere the presence of the streams and rivers starts the Wheel into first motion; the soil comes to life, its uncountable populations take up their abode, the humus is accumulated, the green carpet springs.

We admitted at the outset of this book that we do not really understand the origin of life and that we probably never shall. But we do know that protein is the vehicle or the agency by which life is conveyed; we are here on the edge of a mystery which still eludes our knowledge but which may become clearer with time. We know further that protein is various. There are innumerable forms of it. There are minute specks of protein in the soil, there is vegetable protein and animal protein. As if aware of the supreme value of the final stages of the preparation of her soils, Nature has designed a special agency or instrument -- it is difficult to choose the right word -- to insure that these most essential life elements, the proteins, shall be abundantly and above all safely transferred from the soil to the plant; having endowed the soil richly with a supply, she takes measures to secure the smooth transmission of these intensely important substances to the next of her creations, the green plant. One of the means by which this is done is known as the mycorrhizal association.

The mycorrhizal association is an association between the *mycelium* in the soil and the plant root. It has been described as a living bridge, and it is a fact that it is itself alive and connects two things which are also alive, namely, the plant root and the soil fungus;

mycelium is only another word for fungus and soil *mycelium* means the fungus found within soils. In describing the changes which take place in a compost heap we mentioned thin threads of grey matter clinging to decaying roots and twigs; similar threads can often be recognized attached to the roots of plants which are still growing. But this is not all. The microscope reveals far more; it shows us these thin threads of living matter being drawn in by those roots, and finally their digestion by the plant; every phase of this can be followed and studied under the lens. (The microscopic technique is advanced and has been perfected by Dr. M. C. Rayner and by her assistant, Dr. Ida Levisohn. Dr. Rayner has been a pioneer in the investigation of the mycorrhizal association. See Trees and Toadstools by M.C. Rayner, 1945.)

This remarkable process is a true symbiosis or living together (see Chapter 2) in that it is beneficial; the *mycelium* which attaches itself to the plant root is no enemy to the plant, no parasite; it is an enricher not a plunderer. Quite a number of fungi have been found thus to be linked with certain trees, especially with conifers; indeed, there are cases in which a plant organism is unable to complete its life cycle unless it has such a fungus as partner attached to it. This was not appreciated until lately. Mycorrhiza were first investigated by Frank in the 1880's, when at the request of the German Government he undertook researches into one such fungus, the truffle, with practical aims in view. From that standpoint the research was rather a failure, and the scientific side of the subject also remained somewhat of a dead letter. It is only recently that attention has been revived, and it was not until the intimate bearing of the mycorrhizal association on soil fertility emerged that the whole subject assumed its proper place and importance.

The first fact which has been established (specimens were collected by Sir Albert Howard from India and Ceylon and at his instance were procured also from South America and many other countries) is that the mycorrhizal association extends far beyond the tree world to which at one time it was assumed to be confined. The following cultivated plants have been proved to be mycorrhiza formers: tea, coffee, rubber, sugar cane, cotton, rice, maize, wheat, banana, cacao, vine, custard apple, mango, lime, guava, peach, san hemp and other tropical leguminous plants, many species of clover, tobacco, and so forth; the association appears to exist throughout the great grass family (this includes the cereals) and -- what is interesting -- also among the nodule-forming plants; in fact about 80 per cent of cultivated plants are mycorrhiza-formers. The mycorrhizal association is therefore no isolated curiosity in Nature, no speciality of conifers or a few forest trees; it is a prevailing and wonderful system.

How has it come about that this has escaped notice? In the first place, mycorrhiza are only present when there is humus in the soil; this has been established beyond dispute. As much of our research has for years past been conducted on plant specimens from soils poor in humus it is not in the least surprising that the presence of mycorrhiza escaped notice; they escaped notice because they had ceased to exist. Something may also be attributed to the delicacy and difficulty of the microscopical technique called for. But the principal reason why so little attention was paid to the mycorrhizal association until lately was no doubt the fact that only a portion of the plant's nutriment is conveyed by this means; much of what the plant needs is sucked up from the soil solution by the ordinary action of the root-hairs. The elaborate and as it were roundabout process which induces first the independent growth of a fungus conjoined to the root, then its absorption, and finally its disappearance, all in stages, appears at first sight to be a subordinate route for the passage of food materials.

It would seem that this inattention on our part is a mistake. The mycorrhizal association is of cardinal significance. The invading *mycelium* contains 10 per cent of nitrogen -- this is a very high content -- and it seems clear that these fungi have the capacity of handing on their protein to the plant in a very special way and that the subsequent synthesis or building up by the plant of its own protein is done in an ideal manner. Where the mycorrhizal association is absent, this perfect synthesis is not accomplished, and in some way, somehow, the protein which the plant builds up is of inferior quality. In energizing her soils for the use of plants Nature has provided something rather special for the purpose of transmitting the life principle both smoothly and also with an ample margin. For the mycorrhizal association is undoubtedly in the first place a safety mechanism and must be primarily regarded in that light.

If this is so, the question at once arises: what of the 20 per cent of cultivated plants which are not mycorrhiza formers? How do they manage? The question is important. In view of the fact that the nodule-forming plants, which are supposed to be the great suppliers of nitrogen to the soil, nevertheless indulge in this extra means of catching at nitrogen (apparently mycorrhiza and nodules are not always found on the same root), which is certainly rather surprising, the query is one which ought to be answered. The presupposition is that in the absence of the mycorrhizal association there must be some other method by which the plant insures itself an extra intake of protein or of its digestion products. The fact that not even the nodule-forming plants, in spite of their own special capacity for fixing nitrogen, dare forego this method is surely most instructive.

There is no certain knowledge as yet of what these other methods may be, but there are some suggestions. (Howard: *The Soil and Health -- Farming and Gardening for Health or Disease*, p. 35.) It is possible that the needed intake of protein is accomplished by means of the absorption by the root hairs from the soil solution of the digested products of the dead bodies of the soil microorganisms *before* these break down completely into the inert form. These specks of so-called dead organic matter are also rich in protein; to that extent they are still alive. What we may call the plant's normal procedure is to wait until these bodies have finally become mineralized into simple nitrates to be held in the soil solution and absorbed therefrom. But is it not possible that the root hairs may also have the capacity of catching these substances at the intermediate stages, before they are completely inert, we may say, before they are completely mineralized? In that case there would be a very definite link with the biological content of the soil while still alive, which could be parallel to and could replace the mycorrhizal association. Indeed, we cannot yet tell how many such other links there may be between the protein of the soil and the protein of the plant. It is certain that there is a more intricate connection than we had realized, and that there are facts of crucial importance still to be discovered. The suggestion that we have here a still uncharted field can be based on the observation, which has been established in a number of cases, that nonmycorrhiza forming plants like the tomato nevertheless reveal exactly the same qualities of stamina and health and taste when grown in a humus-rich soil as do the mycorrhiza-forming plants and also exhibit exactly the same weaknesses when deprived of humus. Incidentally this suggestion gives a very good explanation of why some cultivated members of the cabbage family possess such a very diffuse root system and such elongated root hairs; they would need these, if, not being mycorrhiza-formers, their roots have this extra duty of combing the soil for the specks of disintegrating protein.

This does not exhaust the possibilities. Investigators (the pioneer investigator on these aspects is B.F. Lutman, author of *Actinomycetes in Various Parts of the Potato and other Plants,* Univ. of Vermont and State Agricultural College Bulletin 522, 1945) are just beginning to discover other very delicate forms of symbiosis of protein-rich intercellular filaments *(Actinomycetes)* within the plant. Their function has not yet been elucidated with certainty. If however they do contribute to the synthesis of the plant protein which seems likely, they would be a kind of internal mycorrhizal association. The potato is one plant whose life cycle and reproductive powers may be only explicable in the light of further knowledge on this point, the bearing of which may be rather wide. The history of the wild and cultivated potato is indeed a most extraordinary one, which would repay further investigation.

The mycorrhizal association can best be appreciated if it is assumed to be one out of a number of arrangements instituted by Nature, part of a general system. There are evidently what we might almost call secret and concealed mechanisms devoted to preparing and transferring the proteins which have to pass from soil to plant. How far such secret mechanisms occur farther along the great Wheel we have no idea, but the vitamins are in all probability something of the kind linking up the plant with the animal. This synthesis of proteins is the thin red line which runs through the biological life of our planet. In the ordinary way the plant commands more straightforward means of feeding itself; its daily intake of raw materials is given to it from the soil solution by the suction of the root hairs. It can exist on that basis alone. But its existence is then an imperfect and precarious one, and sometimes forbids the consummation of the life cycle, namely, the setting of flowers and the ripening of fruit.

If then the passage of protein is of this supreme importance can we do anything to aid it? Can we assist Nature's alchemy in the same way as our cultivation operations assist her own wonderful methods of aeration and drainage? We do not hesitate to dig and delve and turn and hoe, and though our efforts are clumsy indeed as compared with those of the earthworm and the ant, yet they are powerful aids in evoking richer harvests than we could otherwise obtain. Can we in the same way directly add something to the store of nutritive material on which our crops might draw and thus enhance their amounts and volume? For just as Nature links her physics with her chemistry and operates simultaneously and often by means of identical agents in either field, so might we add our plant-feeding arrangements to our cultivations: the final preparation of the soil is our business no less than hers.

The answer to this pertinent question is both yes and no. We can add to the plant's nutriment with far-reaching results; but we must do so within the limits and by the methods laid down by Nature.

Our ordinary means of adding nitrogen, carbon and the other elements that make up the plant's food materials including its protein have already been discussed; they include animal and green manuring, composting, a supply of water, the use of the algal film and of the *Azotobacter* group. These contributions of material are in principle straightforward, even if we often contrive curiously to deviate from the path in attempting them. But they are always in the nature of an ultimate return of what already belonged to Nature's living soils; they are wastes which have themselves recently been part of a living system and are now being replaced at the point from which they were lifted up into the active cycle; they are never additions from an alien kingdom. Perhaps the atmospheric gases, oxygen and more especially the inert nitrogen, might seem at first sight a contradiction to this principle, but there appears to be so intimate a circulation of these gaseous elements between soil and air that they can be considered soil constituents no less than the soil elements; the atmosphere actually penetrates into the soil and inhabits it and must be looked on as a soil component, just as water is a soil component.

In attempting to supply extra nutritive elements from outside this already comprehensive section of the Wheel, we are bound to intrude into a different sphere: we cross over, as it were, a significant boundary. This is the boundary between the dynamic and the static, between the living and the non-living. We enter that mysterious zone, that elusive no-man's-land of which we know so little though our eyes always scan it with so much anxiety. In this land we shall find that our authority has ceased to run. It is impossible for us to add directly from remoter sources to the intensity of existence on this planet; all we can do is to create conditions favourable to, Nature's own methods of intensification and thus indirectly to stimulate and enrich her results.

This important principle needs to be stated because it has been contravened. There is a great temptation on us to add to the resources of material existence. We live under the shadow of fear -- the fear of scarcity. This fear has troubled us not only during the present period of upheaval, famine, and disturbance, but for many years past. It has particularly beset our minds since one great scientist (Sir William Crookes at the British Association for the Advancement of Science at the end of the nineteenth century) pointed to the apparently growing disparity between the numbers of human beings destined to be born into the world and the amount of food which he believed it would be possible to grow for them. It was therefore with relief that men heard the advice of agricultural science not slowly and carefully to intensify Nature's production but quickly and rapidly to force up her activity: to make weighed and measured additions to her current stores of raw materials for the plant and thereby to increase above all the volumes of crops.

We were not to wait until the roots of trees fetched up for us the mineral wealth lying in the subsoil and rocks; we were to seek the numerous outcrops of such substances as phosphates and potash deposits and ourselves to collect these and give them to the soil. When it was discovered during the first World War that we could also by means of a new invention catch the atmospheric nitrogen and transform it into a portable and purchasable material, the scheme seemed complete; the three great raw materials for plant growth -- nitrogen, phosphorus and potash -- would be available in unmeasured quantity to relieve our anxiety and if carefully and justly allocated would immensely increase the food supplies of humanity.

The plant food materials thus to be procured by mining or manufacture were candidly described as artificial, a name which has since been deprecated, but which nevertheless conveys the truth; for they are all alien substances from the point of view of the growth of the plant. The theory which underlies their application goes back roughly a hundred years, but their extended use only dates from after the turn of this century. Their inventors and advocates have until recently referred to them with pride, and have been not a little surprised to encounter the keen and biting criticism which is now being directed against them.

The starting point was Liebig's chemical researches in the 1840's. This great scientist put order and sense into what had until then been a subject for the most erratic speculation; he helped to make organic chemistry what it is. On the question of plant nutrition he carried out a series of experiments which swept away many current delusions and put certain facts on a firm basis. These facts were in his own domain, that of chemistry. By burning plants and analyzing the ash, he was able to establish beyond controversy what mineral elements went into the structure of plants. He made a further deduction, and here he was less well-inspired. He argued that these minerals could be given to plants from an extraneous source in whatever quantities were desired and that the plants, making use of them, would show a corresponding increase of growth.

Thus artificial manures were born out of what we may fairly describe as the NPK mentality (NPK from the chemical formulae N for nitrogen, P for phosphorus and K for potash [Kalium]). Though their widespread popularity is, as has already been stated, a comparatively recent phenomenon, their use was continuously kept before the public mind by certain famous experiments on the Broadbalk field at Rothamsted; these experiments date back to Liebig's own day, for it was one of his own friends who instituted them and left money for their continuation. They were designed to show the effects of artificial manures on cereals and were still claimed only the other day as "the greatest contribution ever made to the art of food production". (C. S. Orwin in *The Sunday Times*, 14 October 1945.) The very searching criticism now being directed against them throws great doubt on this claim. (The criticisms attack the trials at their core in maintaining that the methods employed have been inherently unsound and the results therefore unreliable. Two principal defects stand out: the small size of the plots, rendering them liable to earthworm invasion from outside: the use each year of fresh seed procured from elsewhere; the latter defect invalidates the evidence of a hundred years. These criticisms, which yet await any answer, will be found set forth in Howard: *The Soil and Health -- Farming and Gardening for Health or Disease*, pp. 79-80; this author's description of the appalling state of the plots when visited by him about 1919 should be read.)

Let us recall briefly the processes of nutrition. The organic matter in the soil, i.e. the principal part of the humus, is constantly combining with the oxygen of the atmosphere and of the air in the soil spaces. This slow oxidation releases energy enabling the living soil organisms, existing in incredible numbers, to do their work, which is to attack the oxidizing matter and break it down into simple salts, nitrates, etc. These salts in turn, dissolved in the soil solution, constitute the raw materials for the food manufacture of the plant, which sucks them in through its root hairs. In these processes, which follow on each other, there is a balance. The work of the soil organisms is adjusted to the amount of the organic matter in process of oxidation ready and available for them; as they eat it up more is being manufactured; the consumption processes at the latter end are always being made good at the starting point. The result is a layer of humus which is remarkably stable both in amount, i.e. depth, and in quality.

When a dressing of artificial manure is given it might be imagined that all that was being done was to introduce quickly and easily at a comparatively late stage in the chain of processes an additional supply of those salts which are being laboriously produced by the soil organisms; the plant should proceed to feed abundantly on this enhanced food store; the whole thing should go forward more rapidly. But this is not what happens. The chain of processes instead of being sped forward is diverted or may even be described as reversed. The additional salts do not simply lie there while the plant gradually eats them up; on the contrary, they start another cycle. They stimulate the life of the soil organisms, and do this to such an extent that these organisms begin to comb and devour the soil humus for every thing they can get. They go much further than they have ever gone before, for in their frantic search for food they sometimes attack the nitrates which they themselves have produced, entering into rivalry with the needs of the plant to the eventual detriment of the latter, and finally invade the colloidal glue or paste which holds the compound soil particles together, glue which is itself an organic substance. This glue is not ordinarily subject to their attacks. The glue is composed of the bodies of dead bacteria; it is therefore rich in nitrogen; the living bacteria, in fact, are feeding on their dead brothers. Here is a perfect example of cannibalism, for it arises, just as cannibalism in the human race arises, out of an unsatisfied craving for protein on the part of a protein-dependent organism.

The result is a strange degree of superactivity. The slow crumbling down process, the making and remaking of humus, yields to an intense glow, a sort of fire; the soil is correctly described as burnt up. This fire, like all fires, is destructive, for the glue once consumed is not restored. The compound soil particle falls apart; a dusty condition sets in; the land "blows".

The soil population, in fact, has been so stimulated as grossly to have outstripped its food supply; it has eaten like a starving creature, which in these conditions it is. Indeed, it is not difficult to realize what happens. The soil humus is being used up. Nature's working capital is being transferred to current account; and there is no replacement.

This wasteful and extravagant practice has all the results we might foresee. At first there is considerable stimulation of plant growth: large dark green foliage is formed: fruits and flowers increase in size: there is an apparent initial success. This may last some time, and it is obvious that the period depends on how great is the original store of humus which can be burnt up. But when this precious capital is exhausted, the true effects are to be observed.

(Almost all comparative trials of artificials and other manures break down in accuracy on this point; the humus present everywhere bolsters up the action of the artificial fertilizer for a period. The only true comparison would be in experiments done on the bare subsoil.)

The first effect is physical. The compound soil particles fall apart into dust, which either sets itself into a dense mass preventing the pentration of air and needing constant reworking (an effect very noticeable to the cultivator) or disintergrating into a lifeless powder which can be carried away by wind in one of those destructive dust storms which we have already noted. It scarcely matters which disastrous condition confronts us. We have wasted our store of humus: we have destroyed the food of our faithful allies, the soil bacteria: they have now perished: the soil is dead.

So notorious have these effects become that a general retreat all along the line has had to be made. It is agreed that the physical condition of the soil must at all costs be maintained. No one is now so enthusiastic an advocate of the presence of humus in the soil as he who wishes to use artificial manures. Humus, it is argued, must be insured, but surely it is possible to use these extra amounts of plant raw materials as well? Are they not, after all, themselves natural, part of Nature's wealth? Where can be the harm in conducting to the root of the plant an additional supply of the mineral wealth it needs just as we conduct an additional supply of air, water or organic manure?

It is not altogether an unreasonable thesis; indeed, it is the old Liebig thesis restated. The temptation not entirely to abandon the use of artificials after years of their use and in face of the constant pressure from authority is very great. What harm can we apprehend from their introduction provided only that we manage to guard against their abuse in bringing destruction of the physical soil texture?

What we have been learning in this chapter of Nature's own methods of dealing with her soils will direct us to an answer. Artificial manures kill the earthworms outright; they ruin mycorrhizal association; they destroy quality and lead to the loss of reproductive power. This is Nature's first categoric NO to the use of such unsuitable means. Her further unmistakable answer is conveyed in the form of warnings which by now ought surely to be sufficient, namely, in the modern spread of all types of plant and animal disease. To this, Nature's own final condemnation of the use of these manures, we shall have to devote a lengthy discussion which had best be reserved for our following and last chapter; for the present, therefore, we shall confine ourselves to the first effects mentioned.

On the earthworm population the effect of artificial manures, especially of the acid-forming manures such as sulphate of ammonia and superphosphate is of the nature of a cataclysm: a single heavy dressing overnight of sulphate of ammonia will strew them on the surface so that their dead bodies can be ,wept up by the shovelful in the morning. (Sulphate of ammonia is advocated as the most effective means of clearing tennis lawns of earthworms. U. S. A. Dept. of Agriculture; *Farmers' Bulletin 1569,* 1935.) Poison sprays -- those offshoots of the artificial manure idea -- will do the same; after one application of tar oil or lime sulphur in the orchards of Kent the ground is often a carpet of dead worms. Owing to the earthworm's habit of reinvading a territory the effect is best seen where artificials have been used for a number of years over very large areas. This has taken place in the great potato-growing areas of Lincolnshire, where now there are few worms to be found.

There can be no doubt that other life perishes with the worm, the grubs, the beetles, the insects generally, probably the whole microfauna. What is the result? Just what we should expect; the thousand aerating tunnels fall in, the infinitely delicate drainage and aeration provided by these creatures ceases, the soil degenerates -- the ploughman is gone. Is it surprising that in these potato fields of Lincolnshire we see in our own country the first signs of the dust bowl, that final result of the wind and sheet erosion which has wrought such terrible destruction in other countries?

But there is more to face than this. There are complicated organic changes to account for. On every two acres of land in good heart the earthworms are so numerous that their bodies would aggregate a full-grown bullock -- on every hundred acres of good land we have the equivalent of fifty underground cattle. The sudden addition of this quantity of animal organic matter to the soil content must have a marked effect. It is the possible explanation in part of the initially stimulating effect of a dressing of such manures. Curious though it may be, this subject has never been worked out, but it is not to be disregarded. It is consonant with the general extravagance which attends the use of artificials. Nature, as we know, allows about one-tenth of her earthworm population to die annually and adds their bodies to her soil organic matter; in our insane haste we slay this whole population outright, not even troubled to know that we are doing so. How long this addition lasts as fertilizing material it would be difficult to say; general experience would suggest that it can operate for a season or two. Then come the unmistakable permanent effects. The earthworm is no longer there as alchemist, let alone as ploughman. Those casts of his, rich in phosphates and potash, have disappeared-the whole biological condition of the soil becomes impoverished.

Is it surprising in these circumstances that the mycorrhizal association also ceases to function or at least to function properly? We called it a *symbiosis*, a living together, and the implication is that it operates between substances and agencies which are themselves alive. If the soil population is dead it is impossible to suppose that it can continue; nor in fact does it. Where it can still be found it is never carried to its proper fulfilment; investigation has shown that the breakdown comes in the processes of digestion of the fungus by the root; this digestion, as the microscope shows, falls to be consummated when the soil is sterile. In truth the soil population including the earthworm, the insects and the invisible microfauna, the humus in the soil, and the *mycelium* which is the bridge leading towards the plant root and ultimately therefore towards the green leaf, are so intimately bound up together that it is hard to describe one phase of this existence without implying all the others. In fact, humus, fungi, and bacteria, earthworms and other soil fauna, are one world; they exist together or not at all. We must therefore reluctantly come to the conclusion that any attempt on our part to short-cut these well-established connections and put a supply of minerals directly at the disposal of the plant roots will never be satisfactory. The attempt to do more for ourselves than Nature is willing to do for us is bound to end in disaster. The temptation is born partly of greed but more largely of fear, motives which dominate us to our detriment. The true cultivator should not yield to these emotions -- they are out of place in his great occupation. He should trust to Nature: not necessarily with the worship appropriate to a religion, but with a sound respect based on observation, understanding, and proved experience. She is the greatest cultivator, and the greatest alchemist whom he is ever likely to encounter: he will do well to follow all her indications and to obey all her laws.

There is almost no end which we can foresee to our use of the green carpet. It is true that there are no longer many unknown surface areas of this planet to be opened up: it is forgotten that we can equally well delve downwards and by proper working and treatment of our soils increase our available acreage many times; the increased surface that comes from increased pore space in a well-cultivated soil adds thousands of square yards to our fields. Nor need we stop here. We can maintain Nature's alchemy in such a form as will best assist her own operations, insure to her the return of all she needs, see that this material is constituted as she wishes, and so speed up her fertility cycle to an unbelievable extent. The idea that the earth can now do no more for us, that we have reached the saturation point of human possession of this planet, is nonsense: there are vast stores of wealth in the shape of future food awaiting us: we have only to seek these stores in the right way.

The fear of scarcity -- this great fear which is still doing so much harm to our thought and so distorting our emotions -- need not pursue us. It has been far too dominating among us, and a much more hopeful, more cheerful outlook would do us good. The world needs hope, and we should fix our minds on the unquestionable bounty of Nature, which is really there, which truly does exist, of which we ourselves are a part, and to make use of which we are endowed with so extraordinary a capacity. It is not necessary to assume our existence as the central point of the universe or to suppose that Nature leads up to ourselves as a final end: on such topics we may think as our individual beliefs direct. What we all must agree in stating, what we must acknowledge to be a fact established by scientific veracity, is that in the world as we know it, it is possible to pursue human existence, not on a precarious basis, but in satisfying, safe and universal plenty for all the peoples of the earth.

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The Earth's Green Carpet

By Louise E. Howard

Chapter 9
Disease as Censor

In the end Nature takes us in hand. As always any who disobey her laws invite their own retribution. Disease is her reply to those whose actions are in flagrant contradiction to her commands.

The place of disease in Nature calls for some reflection. How does it arise? Why does it occur and where? What does it do? How is it combated? Let us take some of the easier questions first. Disease is not introduced by man. It occurs in Nature and always has. It is found in wild life, sometimes in quite severe manifestations. Epidemics among wild animals are by no means unknown; even our very healthy English hedgerows show occasional diseased bushes or branches or plants. This is significant. It suggests that disease has a place in the natural order.

Disease is the means adopted by Nature for removing the unfit; it may be considered a normal accompaniment of old age when the organism is worn out, as is clearly seen in the case of trees; old trees are usually diseased and this condition advances on them until they cease to live. A tree is a very resistant organism so that its death is a slow one which we notice. In the case of a smaller plant the resistance is less and the plant perishes more quickly. Disease is, in fact, only another aspect of that interlocked life on which so much stress has been laid in these pages. The immediate agents of disease are parasites, insects, fungi, and bacteria; these are themselves forms of life. It is their battle with the host on which they prey which we are watching. This battle is no *symbiosis* like the mycorrhizal association. Emphatically it is no living together; on the contrary, the life of the invading parasite, fungus or bacterium, spells the death of the host. But it is a living process, all the same, part of the continuous round.

Disease is the beginning of Nature's composting. So carefully does Nature prepare those all-important processes of decay -- she has the hardihood, the courage to start on the living plant or animal. This is the real function of diseases; they are Nature's censors, whose duty it is to mark the imperfect organism, condemn it, and then start the execution of the sentence by preparing it for transformation into those lower forms of life from which everything starts again.

Now we see why Nature does not fight disease. Why should she fight what is her own arrangement? In Nature there are no preventive measures against disease; there is no burning of infected material; no attempt whatever at removal; absolutely no segregation or quarantine. The diseased organism continues in free and close contact with its fellows, who are exposed to full infection. This infection may spread -- the inference is that it spreads to what is also unfit. If it could spread to the fit -- with no preventive measures at hand and no segregation -- life would soon cease. But life does nothing of the sort: it continues richly and abundantly. *This is the one proof we need to tell us that disease cannot attack the healthy organism:* the simple fact that we are alive in a world which is alive.

Disease is no enemy: it is a part of the natural cycle; it has a function in Nature: it enters into the Wheel of Life. If it spreads unusually or becomes widespread and severe, this is merely a sign that the bodies or organisms attacked are lacking in some vital quality; they are imperfect, and something else, another form of life, a different creation, replaces them.

We have mentioned parasites, fungi and bacteria, as the immediate agents of disease. But to leave it at that, to describe them as the causes of disease is to misconceive the whole question. Their depredations are acknowledged, but we want to know what it is that invites them to invade the host? If we could answer this we could answer a great deal. Mr. McDonagh, a distinguished English investigator, has put forward an explanation which is most illuminating. *"Every body in the universe,"* he declares, *"is a condensation product of activity. Every body pulsates, that is to say it undergoes alternate expansion and contraction. The rhythm is accentuated by climate. Protein in the sap of plants and in the blood of animals is such a body... If the sap does not obtain from the soil the quality nourishment it requires, the protein overexpands. This over-expansion renders the climate an invader, that is to say, climate instead of regulating the pulsation, adds to the expansion. The over-expansion results in a portion of the protein being broken off, and this broken-off piece is a virus. The virus, therefore, is formed within, and does not come from without, but protein damaged in one plant can carry on the damage if conveyed to other plants. The protein in the blood of animals and man suffers the same damage if it fails to obtain the quality food it needs."* (This is a very much shortened quotation from a statement supplied by Mr. McDonagh to Sir Albert Howard [*The Soil and Health -- Farming and Gardening for Health or Disease,* pp. 187-8]. This statement is itself a summing-up of Mr. McDonagh's long book, *The Universe through Medicine.* Mr. McDonagh goes on to explain a third factor which affects man and animals, namely, the invasive activities of the microorganisms resident in the intestinal tract; these have played their role for so long that they have given rise to microorganisms which can invade from without; nevertheless, microorganisms do not play the causative role in disease with which they are usually credited.)

The general result of the thesis put forward is that *"there is only one disease"*, which has its origin in the damage suffered by the protein wherein the host's disease-resistance lies.

This thesis on disease has not yet been generally accepted nor indeed is it popularly known; it is still at the stage when the language used to set it forth is highly technical. It is, however, a very reasonable and above all a very wide theory. It has the surpassing merit that it assigns to disease a place within the natural order and relates it to other manifestations of natural law; it leaves behind once for all the inhibition which causes us to look on disease as a phenomenon apart.

Even if we do not finally adopt it as our working theory we must agree to see disease as an integral part of the Wheel of Life. Provided that certain conditions obtain , but only if they do obtain, then the higher organism which is sensitive to these conditions yields place to the lower; the parasite, fungus, or bacterium, invades the host to its detriment. There is here a contest of two forms of life, for as we have said, parasites, fungi and bacteria, are themselves Nature's living creatures. They have their rights of existence; we may say they have their function, which is that of assisting in removing the imperfect. Even from our human point of view we may look on them as a most useful range of Nature's workers destined to point out to us our follies and to condemn our mistakes.

How far does this censorship extend? What is the proportion of disease to health in our world? There is no question but that health prevails; there is enormously more health than disease among ourselves, among animals, and in the plant world. Health is our birthright and the birthright of all living creatures. We shall do well never to forget this, for it is the most important of all the facts which we have to grasp.

Moreover, there is a stage beyond which the censorship does not operate. Nature has her limits in this matter; not even the parasites, fungi and bacteria, can escape her severe dominion; when they have fulfilled their part, they pass away. When the diseased organism has finally decomposed, the chain of disease is interrupted. The disease organisms may survive independently for a time, but there is no mechanism by means of which they can continue for long apart from a suitable host; if they reappear it is because such a host is provided. Otherwise they perish.

Nature's arrangements for disposing of diseased matter are indeed more than adequate. They are not violent like our fire or poison sprays; they are less combative, but they are effective. She merely drops the diseased matter on the ground and starts again. With the return to the soil of decaying matter, in whatever degree that matter is itself diseased, disease ceases. With the final turning of the Wheel of Life there seems to be, by some process in which we can but rejoice, a fresh start; the impoverishment, the sickness, the lack of condition, which have been so consistently handed on from one group of created things to the next, vanish when the Wheel makes full circle.

If a healthy soil thus refuses to offer a final welcome to the organisms of disease, the explanation is no doubt to be sought in the fact that here the Wheel drops below the level of what is alive; it dips into the inert stage of existence. The bodies of the soil organisms, and these include any disease spores which may for a time survive, break down into the mineral condition; whatever it is that we call disease cannot conceivably here survive. (It might possibly do so by some process corresponding with the *Actinomycetes*, i.e. where the protein chain is handed on before the inert stage is reached. There is a hidden field of investigation here. Disease is, of course, also handed on from one *living* body to another *living* body, namely, by inheritance from parent to offspring.) That is why we so commonly think of the kindly earth as a purifier. This is a correct conception and one that does justice to Nature's wonderful moderation and self-control in staging the long battle between disease and health.

The supreme fact that emerges is that we have to trace the chain, whether of health, whether of disease, back to the soil. If disease ends here, so does it also begin; if, on the contrary, there has been health, so does it continue. It is in the soil that Nature locates her first bit of machinery -- that mass of organisms which being alive create a superb fertility; from the superb fertility should be derived a superb vegetable growth -- the earth's green carpet -- which passes into the stomachs of animal or man, who thus in turn partake of their share of perfect health. But the opposite is also the case. Any weakness in the soil is passed on to the plant, from the plant to the animal, and presumably from plant and animal together to ourselves.

Let us apply our ideas in the first instance to plants. As this question of disease is still at the stage of acute controversy, we shall from now on base our narrative on a given example or examples. These will be set forth in brief without details and will all be drawn from actual farming or gardening experience. Some will be important and on a large scale, some simple and quite casual. Though limited in number they will be typical and will serve to represent a body of supporting evidence which is gathering volume from day to day and which is open for examination and argument to all who care to consider its bearing and significance.

There is the question of climatic boundaries; we are not to contravene these. In other words, we have not the power and probably never shall have to make an arbitrary geographical or topographical distribution of crops; we can only place in certain environments plants suited to these environments. This means that we must have regard to soil-type, level, temperature, moisture, wind force, and all other factors which may be brought under the heading of climate in the wide sense and consider their relation to the plants within their influence. As a matter of fact, the limits of our action become quite clear in agricultural operations; plants suited to one locality frankly will not thrive in another. Once we recognize this principle it is easy to apply in practice, and undoubtedly some incidence of plant (and animal) disease would be avoided if the rule of right distribution were rather more strictly observed.

(It has been argued that, in order to invite disease-resistance on the lines indicated in the text, we must confine ourselves entirely to those plants which are native and indigenous to an area; transference of a species from any part of the world to any other breaks down such quality of this kind as it may have. Incidentally, this would eliminate from Europe practically all our useful vegetables, including the potato, and much of our fruit; it would even eliminate wheat. To argue thus is to ignore all Nature's elasticity and adaptive capacity. it is only when we go too far and try to grow species which are thoroughly unsuitable to the conditions (or try to keep animals unlikely to be comfortable in the prevailing climate) that we invite consequences. A good example of the different relations to disease of suitable and unsuitable varieties was experienced at the Experimental Station at Pusa in India in the period 1910-24. Three types of vetch [*Lathyrus sativus*] were grown year after year side by side in smallish plots; of the three types the unsuitable variety was always heavily infected with greenfly, another variety mildly, and the suitable variety never; the infection did not spread. The differences lay in the root systems; only the surface-rooted vetch was able to draw in a sufficiency of nourishment and was properly aligned with the local soil. Howard: *An Agricultural Testament*, pp. 162-3.)

But to a plant "climate" is something much more than the conditions attaching to a particular geographical zone. Climate includes all those effects of moisture, warmth and air with which it is in immediate contact. Leaf and root are equally sensitive and, following changes in these factors, will resist, or quickly succumb to, disease. Now these, and all other incidence of disease, are best studied when no interference is attempted. Only then is the demarcation between health and disease exactly true to natural law. *Our best hope of learning about disease is to allow it to operate unhindered.*

It is therefore necessary in experimental work when disease is to be dealt with, to adopt from time to time this principle of non-interference. A single small example must suffice, but it will be illuminating. At the Institute of Plant Industry at Indore in India part of a small field had accidentally become flooded and was waterlogged in July. On this field a crop of grain *(Cicer arietinum)* was sown; in October, about one month after sowing, the crop was attacked by the grain caterpillar, but only those parts of the field were infected which had been subject to the flooding. The areas corresponded exactly, for, as it happened, a map had been made of the flooded area which could be used for comparison. Nothing was done to check the caterpillar attack, which never spread to the rest of the field nor to the fifty acres of the same crop growing alongside. (Howard: *The Soil and Health -- Farming and Gardening for Health or Disease,* p. 164. Where no contrary indication is given the illustrations cited in the present chapter are from Sir Albert Howard's writings, where full details will be found.)

It is beyond dispute that the insect attack was invited by the condition of those plants which grew on the previously waterlogged soil. (An exactly similar coincidence between waterlogged patches in a field and subsequent disease [Take-all in wheat] is described by Lady Eve Balfour in *The Living Soil,* p. 97.) What is surprising is the really marked immunity of the other plants so fully exposed to infection. Yet is this remarkable? Should we not expect this difference between the healthy and the unhealthy host? Let us take an even more interesting experience, also from experimental work in the East. At Quetta in Baluchistan, attacks of greenfly were observed in the boughs of fruit-trees; it was suspected that faulty aeration of the soil round the roots was the cause. So it proved to be; simple cultivation and opening up of the air channels stopped the evil. But more than this was done. It was discovered to be possible to induce an attack at will or to correct it, and that not merely on the same trees but on the same bough; by over-irrigation while the leaves were forming greenfly were found to settle on the lower leaves; the irrigation was amended and the upper foliage was completely clean; the greenfly never spread from the unhealthy to the healthy leaves -- surely an unexampled illustration of demarcation of disease. Here disease was induced or checked at will by attention to the conditions in which the tree was growing.

Climatic conditions acting as a principle factor are beyond doubt very important in the life of the plant; flood, frost, cold, wind, sun will destroy plant life. But the plant's resistance depends chiefly on how it is fed. It is above all from its food supply that its health is derived. As the sources of nutriment are perfect or imperfect, so will it flourish or invite disease. Let us repeat: *"If the sap in plants does not obtain from the soil the quality nourishment it requires; the protein overexpands... the protein in the blood of animals and man suffers the same damage if it fails to obtain the quality food it needs."* Here is the gist of the matter. We are what we eat; and animals are what they eat; and the plants which both we and the animals eat are what they absorb from the soil; and the plant nutriments in the soil are what is transformed out of the wastes returned to the soil. A soil swarming with life becomes perfectly synthesized protein in the plant.

We are therefore not surprised to hear that those nations who have learnt how to keep their soils fertile enjoy a very marked immunity from disease among their crops. Broadly speaking this applies to all Eastern countries though in various degrees; some Eastern peoples are more perfect in their agriculture than others. But disregarding those differences there is more than a marked contrast between the East and the West on this point: there is a profound distinction. In the demarcation of disease as it affects the growing of crops in the East and in the West the situation that emerges is dramatic. While our crops are swept by every sort of pest, costing us millions of pounds in damage and entailing costly and most laborious preparations in defence -- perhaps every week sees some new nostrum put on the market, while governments join in the merry game with repellent and severe control legislation and streams of warning and advice administered through endless committees, the members of which very faithfully fulfil their given task of tabulating new insect, fungous and virus pests -- the East knows nothing of all this. No

Indian or Chinese or Japanese or Malayan cultivator uses an insecticide or a fungicide, a spray or a tar-wash; he could not afford such things and knows nothing whatever about them. Yet his crops are disease-free; more, they are robust. They will resist conditions which positively invite disease, as when the Afghan tribesmen allow their vines to sprawl over the bottom of ditches in a way most calculated to invite mildew; there is no mildew. Such minor attacks of disease as occur in these peasant cultivations are so negligible as never to be remarked upon; they are a totally unimportant factor; they play no part in the life of the East.

Moreover, this standard of health in crops is handed on for generations. The running out of the variety, i.e. the failure of reproductive power, that bane of our modern agriculture, is unknown in the East. The scientist working on the selection of wheats in India can draw on native varieties two thousand years old; the same is true of the sugar-cane, as is proved by ancient Sanskrit names. There are few, if any, changes in methods of growing; seed is conserved and not imported. This experienced agriculture, localized, self-sufficing and ancient, is not swept by the ravages of disease.

It must not be assumed from this description that plant disease is totally unknown in the East -- that would be a contradiction of natural law and therefore an impossibility. Disease is certainly known, but in the first place it is rare, and in the second place it does not spread. It is in this latter direction that we get so startling a contrast with our own agriculture. In the Harnai Valley on the western frontier of India healthy and diseased wheat exist side by side. A few areas of low-lying wet land are always affected by eel-worm; to the East the wheat continues for a thousand miles without a break, and this wheat is perfectly healthy. Now there is a constant stream of traffic both ways, which means that the cysts of the eel-worm must be borne on the feet both of animals drawing the carts and of man, for no preventive measures have ever been taken; infection must have been going on for years; it has never once spread. The eel-worm has had every chance, but the healthy wheat resists without difficulty and has always done so. Could a clearer. proof be given of the total unimportance of the parasite itself as the cause of disease? It is not the parasite but the unsuitability of the wet soil for wheat growing which starts a chain of weakness rendering these plants proper subjects for attack. There is a similar case of healthy and diseased rice in Bengal, where small deep-water areas of rice are always infected with the Ufra disease, which however never spreads to the bulk of the crop; if it did, one of the greatest rice-producing areas of the world would be ruined. These examples have been on a huge scale and have been regularly repeated over centuries.

It was eventually from the East that illumination came. The practice of the Indian peasant, so successful in its utter contempt for plant disease, gave the clue for a bold departure from the conventional standpoint in agricultural research. It brought back to mind tentative ideas as to the possible knowledge to be gained by allowing plant disease to run its allotted course, ideas which had many years previously been put forth by one of our foremost exponents of botanical science (Professor Marshall Ward of Cambridge). From the combination of Western theory and Eastern practice was born a new theory of disease resistance which has been revolutionary.

The work establishing it was carried out at three very different centres in India, Pusa in the plains, Quetta in the Baluchistan desert, and Indore on the Central Indian plateau. It was initiated by two British scientists, Albert and Gabrielle Howard, who after a few years' apprenticeship to local conditions soon learnt how to grow disease-resistant crops. (The reader should distinguish between the claim that crops and animals can be disease-resistant or disease-immune. Complete immunity is a very rare quality seldom conferred by Nature and something quite outside the usual operations of disease.) First the soil was dealt with and was brought up to the highest standards of fertility. Thereafter, in spite of the protests of colleagues no insecticides or fungicides, no tar oils, sprays or sulphur washes were used; no material was burnt; nothing whatever was done to check disease. Sometimes conditions were deliberately conceived to induce it and in this way to provide infective material next to healthy crops; the infection never spread; the crops, grown throughout on a fertile soil, needed no protection-they could defend themselves. The experimental areas were soon in a flourishing condition; they stood out from the surrounding countryside by reason of their superb foliage and appearance, for the experiments had surpassed local achievements. As one of them was afterwards to declare, they had learnt all that was necessary for healthy crop-growing without disease from two sets of professors -- the peasants and the pests. (Throughout the last eight years spent at the Indore Institute there were only two small exceptions, both in themselves interesting. One, the case of the *Cicer arietinum*, has been described above in the text, the other was a cage of mildew due to an insufficiently fertilized soil; the plant, san hemp [*Crotalaria juncea* L.], in trying to set seed exceeded its strength and its weakness invited an attack of mildew.)

These significant experiences have since been amply confirmed. Evidence gathered from at least thirty countries (see Appendix A) in every part of the world tells the invariable story of healthy crops grown on fertile soil; many of the countries which can be named are our great producing areas and the crops mentioned are the staple commercial crops of our export markets; they' range from cereals to roots, fruits of every kind, tea, coffee, sugar cane, the fibres like sisal and cotton, cacao, tobacco, vine, vegetables; there is no crop that will not respond. The evidence is supplied alike by the large plantation and by the suburban plot; it covers every type of cultivation, Eastern and Western, and includes glass-house cultivation. The experience of the East, where plant disease is reduced to its normal insignificance, is at last being repeated and confirmed by pioneer farmers in the rest of the world. There results are being obtained wherever the soil has been rendered truly fertile.

Particularly convincing are the instances where what may be called a cure has been effected, i.e. where on the same area a diseased crop has been either itself recovered or a second crop of identical species has been raised which has resisted disease. A bold application of composting methods in tomato houses at Romsey in Hampshire (by Mr. A. R. Wills; the experience has been repeated by other growers) secured disease-free tomatoes. In spite of timorous official warnings the tomato haulms, badly infected with wilt, were themselves incorporated into the compost which was to be fed back into the houses; the disease failed to reappear, in accordance with that principle to which we have already attributed importance, namely, that in the lowest revolution of the Wheel Nature herself puts an end to the continuity of disease. The composting process here clearly had that effect, and these particular houses have never looked back.

Tomatoes are a good crop to watch because of their quick growth. Another very simple little example may be cited. A small but very sickly tomato plant, at the very point of death, one out of a number of healthy plants, recovered almost instantaneously and began to bloom with a good dressing of compost, given more as a matter of routine than with any idea that at this stage recovery was possible. Side by side with this small tomato house was an old pear tree, inherited by the owner with every sign of starvation and neglect; indeed, during the first summer when it was being observed it was infected with a huge band of lice crawling up the stem day by day. Here recovery took time, but with ample composting of the bed year after year and good watering, the foliage began to pick up, the life of this obviously old tree was prolonged, and some beautiful crops of very large and exceptionally delicious pears have been reaped. (No spraying of any kind was given, not even a grease-band supplied. Both the last two examples from the writer's own experience in a London garden.)

There are other forms of plant disease. Let us take parasitism of plant on plant, for it is not unusual for one plant thus to prey on another, which, we may be sure, invites the enemy only because it is starved or in some way weakened. The Indian cultivator knows this and at once supplies manure if he finds his sugar cane preyed upon by a species of *Striga;* the *Striga* disappears. Farmers in our own country will cure the nuisance of yellow rattle on their grass by allowing the dung and urine of cattle to fall on the starved meadows for a couple of years, an old practice; this has the effect of restoring the nutriment which the plant requires; it is then able to throw off the parasite. The best proof has been established by some formal experiments carried out in South Africa on witch-weed (*Striga lutea*), which constantly and severely infects the maize crop; dressings of humus at the rate of ten tons to the acre proved a complete cure, and the disease-free crop formed an excellent contrast to the control plot alongside, which was a red carpet of the weed. (Experiments of Mr. Timson reported to *The Rhodesia Agricultural Journal*, October 1938, and confirmed by official experiments at the Rhodesian Witch-weed Experimental Farm: see *An Agricultural Testament*, p. 79 and *Compost News Letter*, No. 5, pp. 17-18.) The use of organic manures has since been advocated by the Union Government for all raising of maize.

The disease-resistance thus conferred by a soil rich in humus is well contrasted with what happens when soil structure and fertility are destroyed by artificials. Long ago the inventor of the Clifton Park system of farming noted the increase in diseases of plants when artificial manures were given and their recovery under humus, and also the good taste and health of potatoes naturally manured as compared with those raised only with some dung and some artificials. (R.H. Elliot: *The Clifton Park System of Farming*, ed. Faber & Faber, pp. 190, 240, 241.) The same differences are constantly being noticed today. A cultivator of a fair-sized ordinary country garden happened to use compost on about one-half of his ground while he gave artificials to the other half; this went on for five years, during which period the peas, beans, onions which were grown on the composted half yielded each year very heavy crops, while the *Brassicas* treated with artificials became poorer each year. Cauliflowers failed to flower, club root appeared, sprouts produced very poor crops and savoys did not heart". (Mr. R. S. A. Lermuth, Gatley, Cheshire, in *Compost News Letter*, No. 5, p. 33.) Another grower, by chance short of compost for one row of his sugar beans, found himself faced with a crop the whole of which was "nice-looking" except the uncomposted row, where "half the plants were missing" and "the survivors were miserable stunted specimens"; incidentally compost added to a hopeless dead soil had enabled this cultivator to produce in three weeks beautiful, healthy and vigorous cabbage seedlings which attracted the attention and opened the purse-strings of passing strangers. (Mr. L.R. McKibbin, Craighall, Johannesburg, in *Compost News Letter*, No. 3, pp. 18-19.)

There are other tests of health besides mere absence of recognizable disease. We have the right to ask for something which shall prove in the plant what we may call positive health, that condition of well-being and of enjoyment of life of which we can all be conscious at some moments. In plants such a state of positive health is well indicated first by taste and then by keeping power. There is a growing consensus of opinion that vegetables and fruit grown with organic manures are far superior in taste to those grown with inorganic fertilizers. So definite is this view that a project has been launched and is well in hand for starting "flavour farms" to produce "flavour food". which may one day be sold at special "flavour shops". (John Drummond: *Charter for the Soil* and *Inheritance of Dreams*.) On keeping power there is some interesting evidence. We have the reliable verdict of the manager of a famous garden in Westmorland where first-class vegetables and fruit are being grown for the northern markets, who remarks that "where fungus abounds in the soil" (i.e. where the mycorrhizal association is prolific) exceptionally long-keeping qualities" are imparted to the crops when stored. Humus-raised tomatoes grown at Quetta in Baluchistan, safely made the long journey through the terrific heat of the Sind Desert and then through the moist, hot conditions of the Indian monsoon in the Gangetic plain down to Calcutta, arriving without damage or loss of quality, thus showing a capacity to withstand temperature changes which would have constituted a severe trial for a much harder fruit. On the Hampshire estate of the Earl of Portsmouth roofs thatched with straw derived from wheat grown with farmyard manure lasted ten years, those thatched with straw derived from wheat grown with artificials only five years. The difference in keeping quality in this instance is striking and depends on estate records; the facts emerged accidentally and were confirmed independently by two old thatchers in Wiltshire, who complained of the poor thatching quality of the modern straw grown on artificials.

The evidence reaches its culminating point in the inability of the plant to set seed and reproduce its kind. The reproductive organs are the most sensitive parts of any anatomy and it is not surprising that they should be affected at an early stage. The disaster is great in view of the vital character of these processes; continuation of the species is threatened. This failure in reproduction -- Nature's greatest aim -- is a growing evil in our commercial crops and has caused the most widespread concern. The constant attention of the plant breeder has to be directed to bringing out new varieties to replace those which the farmer is unable to maintain. This was never done in former times, for the whole science of plant-breeding is comparatively modern; nor, as has already been noted, has it to be done in the East. Now something like a war has developed between the breeders of new varieties of fruits and the growers, the one side bringing the accusation that the variety is allowed to perish too soon, the other that new varieties are not bred fast enough. The matter formed the subject of a revealing discussion at a raspberry conference held at our principal fruit research station, East Malling, on July 9, 1943. The lecturer, a member of the staff of the Experiment Station, stated that thirty years ago many different varieties of this fruit flourished in the favoured districts of Perthshire and produced five to ten tons of fruit per acre; gradually variety after variety had succumbed until by the 1930's only the Lloyd George was left throughout the whole seven thousand acres of this area; then this began to become weaker and was replaced by Norfolk Giant; now a new disease was attacking Norfolk Giant and threatened to destroy this too. Yet it has been found possible, in the case both of this crop and of the strawberry, to send for virus-infected plants and place them next to healthy stock. Far from any spread of the virus from the unhealthy to the healthy stock, the exact opposite happened; the virus-infected plants recovered. In the case of the strawberries it soon became impossible to distinguish the plants; the raspberries took somewhat longer, but finally secured an official pronouncement from an inspector of the Ministry of Agriculture of being completely free of disease.

There was nothing in the least unusual in these essays. Simple rules of good farming were followed, but these on principle included the return to the soil of animal wastes properly composted with vegetable matter. Provided always that this indispensable element of the animal is rendered back to the soil, excellent results can be obtained even without the special care implied in composting. Old gardener's practice in a damp climate in the north-west of England has shown first-class potatoes grown in the same spot year after year for nearly half a century; good farmyard manure was never lacking. What makes this example so interesting, small though it is and in no sense carried on as an experiment or with any idea whatever of proving a point is the way in which it contradicts prevailing anxieties. The use of home-grown seed in potato-growing has for many years been abandoned; fresh seed from other localities is always imported, it being assumed to be impossible to maintain the species in any other way. Yet this is the reverse of what should be, and another small grower, who had turned a derelict grassfield into a vegetable holding and from 1942 onward had the temerity to save his own seed potatoes was rewarded by finding not only that they were fully capable of germination but that they yielded far more than bought seed; the harvest already only two years later in 1944 was seven and a half pounds from one pound of his own seed as against the five, pounds from the bought seed.

Such small personal experiences are convincing, but the full case rests on a mass of accumulated evidence which points the same way. Nor can this be dismissed as uncorrelated seeing that those responsible for this record, whoever they may be, have all been influenced by and are following out a principle, the Law of Return. The plantation owners, farmers and cultivators who unite in relating their observations from all over the world, (see many communications in the periodical *Soil and Health,* mentioned in Appendix B) working in every sort of climate and on every conceivable crop for very various reasons, are yet all working to one plan. They acknowledge certain definite ideas; they realize that they are not groping in the dark, that many years' strict scientific experimentation, carried out with genius, preceded the formulation of the arguments that have stimulated and convinced them. (See list of papers mentioned in Appendix B for the written record of the scientific work carried out in India by Albert and Gabrielle Howard, which preceded or accompanied the working out of the principle of composting.) One deep conviction dominates, that the new doctrine is an old one, that it is only a statement of truths which humanity has always acknowledged however imperfectly, that it is supported by the colossal experience of the Eastern nations and also by our own past history, and that some very salient proof of lack of validity will be required to disprove it.

This salient proof can never be forthcoming. It is impossible to establish any tenets which contradict or even only ignore what Nature so plainly arranges on her own behalf; it is impossible to deny those which at every point make reference to the natural order. Disease among our crops ought to be what disease is in wild Nature -- insignificant. If it is otherwise, if it decimates our sowings or ruins our harvests, if it is in any way a matter of anxiety, it is the consequence of acts of disobedience which have been carried to incredible lengths.

Of the three categories, plant, animal, man, the plant is ultimately the strongest. It can adapt itself to a variety of conditions for a long time; it can manufacture food out of very unpromising material; it is remarkably resistant to injuries. Leaves, flowers, twigs, whole branches may be separated from it, even its roots may be pruned; one-half of a tree may be rent away and the rest will survive. Indeed, it has a unique power of restoring growth and of adding to its structure at any point in its career considerably surpassing the animal's habit of developing compensatory faculties for something lost. Possibly plants taken in the mass appear to us even stronger than they are. Owing to their number we do not much remark the single plant that perishes except when under our special notice in a garden or an orchard. Of the ordinary field crop a good portion has to be affected by disease before we pay much attention. This is a very simple point, but it makes for a certain distinction in our views of plant and animal disease, a distinction which is further fostered by our consciousness of the absence in the plant of what we call suffering.

Disease among animals obtrudes itself on our notice. It is true that disease among wild animals escapes our observation; it is a normal accompaniment of old age; the whole organism is failing. Among our domesticated animals this consequence of decline is exceptional inasmuch as only a few favourite animals, our horses, dogs, etc., are allowed to reach their natural term of years. Our animals kept for utility purposes are mostly slain, some when just past maturity, some even only when approaching it. On this count alone disease should be comparatively rare on the farm.

Another cause of animal disease can be eliminated, namely, insufficient quantity of food. From this many wild animals suffer from time to time. On the farm this can hardly be said to occur; it would not be sound policy to keep animals and fail to give them enough food. Such a mistake must be so rare as hardly to be known. Only in very special circumstances does the domesticated animal meet the danger of starvation. As we have already noted, this is the case in Africa where economic reasons tempt the population to keep too many cattle for the available grass, and also in India, where religious custom enjoins the continued maintenance of unwanted animals. (See Chapter 5.) The result in both cases is a terrible spread of disease. In general, it may be said that the domesticated animals of the East are less abundantly fed than our own, principally because the purchase of feed is out of the question.

Some importance may also be attributed to cleanliness and general care. These can be classified legitimately as climatic conditions; if any neglect creeps in, it might invite disease. Here again we can assert that our Western standards leave little to be desired. Some mistakes may be made (the cold concrete floor now advocated in cowsheds and pigsties compares very unfavourably with the beaten earth floor of the East, so much more comfortable to the animal) and isolated instances of want of care may not be infrequent, but our love of animals, combined with our very clear sense of their commercial value, is too great to permit many errors.

Taking these three considerations together, our habit of not keeping our domestic stock beyond the age of maturity, our willingness to provide them with a sufficient quantity of food, the attention we devote to their care and conditions, disease among our farm animals ought to be rare indeed; it should be almost in the nature of an accident. If it is sporadic or at any rate not insistent in wild Nature, it should be quite abnormal on the farm. How very disconcerting is it to find that the very reverse is the case; that disease is rapidly becoming the principal preoccupation of the stock-farmer, whatever the animal he has to handle, whether a racing stud, or horned stock, or poultry, or pigs, or whatever it may be.

There is no need to bring formal proof of this. It is an admitted fact which it is not possible to deny. (In 1939 out of fifteen technical committees appointed by the Agricultural Research Council of Great Britain twelve were devoted to the study of plant or animal disease. Since that date, in spite of the work of these committees, complaints about disease, especially animal disease, have become even more insistent among our farmers.) A glance at any farming paper will confirm it. Little progress has been made in combating these animal diseases, many of which have appeared recently. In spite of thousands of pounds spent on research into foot and mouth disease we are exactly where we were: we are so terrified of the spread of this infection that valuable herds are destroyed in their entirety rather than allow it a foothold; this desperate remedy is still most rigorously enforced in our own country. The new grass sickness in horses, which is almost always fatal and which has only recently appeared, defies us absolutely. Among the many other disasters with which our able veterinary services also quite fail to cope is an increasing sterility. Sterility among brood mares is very serious; the milch cow's normal twelve calvings in the course of her life have now dwindled on an average to only three; three-quarters of her usefulness has lapsed. This situation repeats in the animal the running out of varieties noted in the plant. Reproduction, the whole end and aim of Nature, for some reason ceases.

What can be the explanation of this most disquieting state of affairs? It is there for us to read if we will only do so. Looking one day at the little flags on the official wall map showing the incidence of foot and mouth disease on the continent of Europe, Lord Portsmouth observed that this disease stopped when the areas of old peasant farming were reached; his observation failed to move the official to whom he was talking by a hair's breadth. (Amusing account in Balfour: *The Living Soil,* pp. 123-4.) Yet the remark was very illuminating; the disease stopped of its own accord where the old mixed farming principles were still maintained.

If this important observation had passed without attracting the attention it merited, the explanation was perhaps that the subject had not yet been fully ventilated. This is no longer the case. A vital thesis has recently been advanced and has been supported by some convincing demonstrations. The thesis again arises out of observations made in India. At the Experiment Stations at Pusa, Quetta and Indore, where so triumphant a demonstration had been given of health in crops (see above), the story was retold with the animal. Three different sets of work-cattle, respectively six, three, and twenty pair, were found to be astonishingly resistant to disease, including infective disease. The degree of resistance amounted to a practical immunity and was indeed amazing; the cattle were never segregated or in any way protected and all inoculations and preventive measures were sternly refused. Now the animal population all round was heavily infected by foot and mouth, Johne's disease, septicaemia, etc., the result in the Indian cattle of insufficient feeding, but even the cattle on the experimental animal farm at Pusa succumbed; with these cattle the draught beasts were seen on more than one occasion to rub noses over a fence.

One accidental case of snake-bite, from which the animal recovered, and one very slight case of foot and mouth, which was also cured by ordinary care, occurred; otherwise there was no disease of any kind. In view of the supposedly virulent nature of the infective diseases with which contact was constantly being made, this record is astonishing; the whole period covered was nearly thirty years (Pusa 1910-1923, Quetta 1910-1918, Indore 1924-1932). The explanation cannot be mere sufficiency of feeding, for the diseased cattle kept on the experimental farm at Pusa were certainly adequately fed.

The draught animals which showed this high degree of disease-resistance were fed off quality food; here the distinction lay. Their feed was derived entirely from the land at the disposal of the scientific department which had asked for them and at the same time taken care to acquire an area of land on which enough could be grown for their maintenance. In accordance with the policy to be pursued in crop-growing all land had been brought to the highest state of fertility, and the chain of health thus started had communicated itself, first to the plant and then to the animal; these, like the crops, proved perfectly able to resist infections. As though to prove the point, when in the first year at the third Station, in 1925, quality food ran rather short because there had not been time to get sufficient crops sown, the animals slightly lost condition; the mild case of foot and mouth already mentioned then occurred. With the putting in hand of the full crop and soil fertility programme the danger was past and did not recur. The condition of these animals was so beautiful that they were in constant demand for religious processions, to the pride and pleasure of the staff.

When this interesting story became known in this country, the question was asked: could the same thing be done again? Though the idea has been put to official quarters, it is to be regretted that courage has not yet been found to repeat in a simple way the lesson from India. No experimental farm has been taken, where the soil could be brought up to the highest state of fertility, then for some years allowed to maintain stock on the healthy crops grown, and where finally the gates could be opened to one or two cases of foot and mouth to be brought into contact with the healthy stock; had this been done, the results might have ended once for all our present most destructive policy of slaughterand of burning. In view of the expense of the compensation involved in our present arrangements and the additional losses inflicted by the standstill orders for all cattle movements in the neigbbourhood of any outbreak, this experiment is overdue.

It has been left for private individuals to do what they can, the law prohibiting, however, the suggested demonstration on foot and mouth disease at private hands. But other animal diseases have yielded ground at a rate which is indeed encouraging. The rapidity with which disease among stock can be made to disappear merely by guarding the chain of health from its source in a fertile soil brings so hopeful an element into the present miserable and disquieting situation as should appeal to all. The public has the right to ask the farming world to take note of this new element and either to follow the pioneers or to disprove their contentions. As these contentions are based on experiences personally vouched for and open to inquiry the doubting attitude must prove abortive; there is no longer any reason why we should not in this island have the advantage of a supremely healthy animal population. Our climate was made for stock-breeding, our reputation stands high; but no animal husbandry can prosper unless founded on the belief that the food of beast and man must be drawn from a fertile soil, unless, in truth, Nature's chain of health be respected from its earliest inception.

The best demonstrations are where a whole farm is raised from a poor to a fertile soil condition to be followed by marked disappearance of stock disease. We have at least three such demonstrations in this country. Contemporaneously with the work being done in India two English farmers (Mr. Bancroft and Mr. Fred Bancroft) instituted a system very like the Swiss, of treating their pastures and meadows with liquid manure; this sheet composting, as it was afterwards acknowledged to be, was continued from 1911 onwards for over thirty years. The farm was a small one of 68 acres in Lancashire, lying high, 850 to 1,000 feet above sea-level. What has been the result? In 1910 it carried 20 cattle; in 1942 these had increased to 56 and a few sheep, the average milk output overtopped quite notably the average for the four nearest local districts, the profits from the farm were similarly distinctly above the local average. But what matters is that the health of the cattle became "wonderful"; that milk fever vanished; that no Johne's disease, which is stated so often to follow on the use of liquid manure, occurred; that T. T. milk could be produced, there being no reactors and the veterinary surgeon declaring the herd the best he visited.

This farming was not intended as an experiment nor was it undertaken by scientific advice, though the results were eventually, out of interest, made known (*Compost News Letter,* No. 4, p. 5 and No. 6, p. 32); it was done as a matter of simple farming practice, on old well-established principles, in fact, on methods handed down from a "father's grandfather". The result was perfect animal health surrounded by an ocean of prevailing animal disease.

In another case principles were eventually worked out after a lifetime of varied farming experience, embracing both milk production and more especially the breeding of valuable racehorses. In the course of this farming career a rude shock was administered when 66 per cent of cows in what had been accounted the premier herd of three counties proved reactors in a tuberculin test. Another seeming disaster was the contraction of contageous abortion by the most valuable of the thoroughbred mares. Both misfortunes were surmounted. The cattle feeding policy was radically revised with a much less wide departure from natural principles; the mare was turned out for two years on healthy grass and at the end of this period was pronounced clean, subsequently breeding four valuable colts in seven years and living to the age of twenty-two. But the real illumination came when a move was made to what seemed a most unpromising site on the Wiltshire Downs, where an acquisition was made of land so windswept, bleak and derelict, so unattractive to most buyers as best to be described as "space out of doors"; this land could grow no good grass and the cattle could only be kept alive by expensive purchase of outside feed. Yet by thorough subsoiling, ploughing and cultivation, by forgetting the poison spray and using organic manures only, this land, after less than seven years of farming, now grows some of the biggest and healthiest crops of grass and wheat that can be found anywhere in England; it produces T. T. milk and was carrying seven distinguished thoroughbred mares with foals at foot and yearlings of a class better than the owner had ever bred previously. Disease, alike of crops and stock, had become negligible. (Description with full details in Howard: *The Soil and Health -- Farming and Gardening for Health or Disease,* Appendix D, "Farming for Profit on a 750-acre Farm in Wiltshire with Organic Manures as the Sole Medium of Refertilization", by Mr. Friend Sykes; a longer account in Mr. Friend Sykes's own book; see Appendix B. It is an additional small point of interest that on this farm the seed used for wheat has been for the last six years home grown; when bought this seed was subject to black smut; this disease is now negligible and the yield enormous. The same is stated to apply to oats and barley.)

The third case starts with a long chapter of disaster on a dairy farm in Somerset. For five years disease drained the farmer's resources and nearly ruined two herds of cattle; abortion and tuberculosis riddled the animals, few calves were born in full time and most of those few which reached full date were dead. Then the whole policy was reversed; the forcing up of the milk production by unnatural feeding was stopped; the fields were allowed to recuperate, and tons and tons of compost, made out of the straw spread in the yards, which replaced the tying-up programme in the winter, brought the soil back to fertility. Three or four years of this kind of farming restored life to a dying farm. Fifteen healthy heifer calves were born in four months; cows formerly sterile were got into calf, one cow, aged fourteen years, after being barren for three years, was due to calve; for two years the herd has been attested. Agriculture of the best type has thus been restored on land which had reached the lowest conceivable level of infertility; the topsoil has virtually had to be re-created, there having been nothing above the subsoil but a little dead dust. Now everything on the farm is teeming with health, from the soil to the animals and also to the farmer and his family full of energy and spirits. (F. Newman Turner: "Restoring Life to a Dead Farm", in *Soil and Health,* vol. i, No. 2, 1946.)

In these three convincing examples of farming experience, but also in many other instances, it is stated that artificial fertilizers were wholly eschewed. It is on a point such as this that the animal can be so well used to give judgment: as we have seen in a former chapter its unbiased instant verdict can be used by the farmer as a guide. The animal's choice of its food, its feeling for palatability, is closely allied with the question of health, indeed, is a part of that question; if forced to forego its natural preference, it will suffer; if allowed to exercise it, it may recover from a bad condition. There is interesting laboratory evidence on this point, showing the exceedingly rapid and indeed amazing recovery made by rats when only a small portion of food grown on organically manured soil was added to a deficiency diet, whereas a comparable ration supplied from seed grown on soil artificially manured proved to have no recuperative power whatever. (Experiments of Mr. Rowlandson and Miss Barbara Wilkinson in *Biochemical Journal,* vol xxiv, No. 1, 1930; abstract with graphs in *Compost News Letter*, No. 4. pp. 31-4.) In the field the results are at least as obvious. A herd of milking cows which had yielded 110 gallons a day when grazing a naturally fertilized field dropped its yield to 70 gallons a day when turned on to a similar field artificially fertilized. (*Compost News Letter*, No. 8, p. 11.) Pigs, on the other hand, will recover from white scour if allowed to eat turves rich in humus or soil from fresh natural molehills (Lady Eve Balfour: *The Living Soil*, p. 125), while one use of a phosphate fertilizer is to reverse the picture and make growth so unpalatable as to "keep the rabbits away". (*Compost News Letter,* No. 3, p. 13.)

There is nothing that need surprise us in such facts. They agree perfectly with what we noted above about plants; artificial fertilizers ruin plant health; this weakness cannot but be passed on. Health in animals is an end condition established out of a long preceding building up. It is the final proof of the proper synthesis and passing of protein from one section of the Wheel to the next. This chain must never be interrupted; it must be guarded; above all, it must go back to its real source -- living soil.

We come to human disease and we come to a difficult problem. Disease, we have already conceded, is a true, a proper, an admitted thing in Nature. It would be a false ideal to suppose that we can entirely eliminate it in our crops or in our. beasts; how then can we hope to do so in ourselves? The laws we are debating are profound; some disease there must be.

Nevertheless we are entitled to rebel against the wide prevalence, the ubiquity of disease in our midst to-day. There is an excess of ill health among us. Each winter sees us subject to colds and influenza and fears about the increase of other diseases only too clearly express a popular apprehension on this subject. This fear is in itself a sign of weakness. People in good health forget all about their health; they seldom mention it; they take it for granted. The early Victorian attitude on the topic of children's health is frequently described as rather brutal, and it was; but it was a brutality which sprang from a kind of strength, which could afford to take health for granted and despise anything else, even in the young. This very simple fact is more significant than it seems. It indicates, it is true, that we have advanced in standards of gentleness and pity, but it also betrays the unpleasant truth that we are much more preoccupied with health than we were a very short time ago. If it is true, to quote only two examples, that we spend £300 millions a year in this country and £700 millions in the United States of America on sickness services, and that without counting loss of efficiency, we are indeed subjecting ourselves to a colossal expenditure and to colossal losses; if it is true that even in a prosperous section of our population less than one-tenth of those examined can be pronounced as in first-class health, (Pearse and Crocker: *The Peckham Health Centre,* Allen & Unwin, 1943, 333 pp.) then it is surely time to look about us and see what we would be at.

Can we draw light from the history of disease? Can we point to useful contrasts between the peoples of one continent or climate and another? Can we find any communities of human beings alive to-day who can supply us with some sort of indication of the conditions which would lead up to better human health? Only brief and general answers can be attempted to these questions, which call for more medical knowledge than most of us possess. But a few facts can help us clear our minds and lay the foundation for whatever instruction each one of us may subsequently be able to acquire.

Perhaps the first thing to note is that the demarcation line between health and disease has appeared to shift to and fro more markedly in the case of human beings than with either plants or animals. There are two possible explanations. It may be really so, because man, being the highest, i.e. the most complicated organism, is also the most delicate in Nature and the way he has lived has increased this delicacy. This thesis has yet to be proved, and perhaps, on the whole, the layman looking on the human body would be inclined to judge it as uncommonly resistant, endowed with remarkable strength, rather than the reverse. It may also be that the shiftings between human health and disease appear to us marked because we have at least some small amount of historical information on what disease has meant in our human past.

Our most dependable records come from Europe, which for many centuries was greatly ravaged by plagues and epidemics. These scourges were known both to the Greeks and the Romans, but were intermittent; they seem to have set in sweepingly towards the close of the second century A. D. It is a reasonable deduction that the cause lay in the rapid deterioration in the fertility of the Mediterranean regions, the soils of which undoubtedly began finally to give out about this time. North Africa, from having been a vast corn-growing granary, turned over to largely desert conditions; Greece, South Italy and Sicily became agriculturally derelict, a condition which has persisted. Restoration was scarcely attempted. The balance was restored by the opening up of new lands, the cutting down of the virgin forests in Germany, North Europe, Britian, the colonization of Gaul and Spain. Fresh races, of remarkable stamina and vigour, flooded in. For a long time the rich stores of fertility in the lands on which they newly settled kept them in good health.

But disaster overtook the peoples. The early Middle Ages were marked by the spread of fresh plagues. The habit of living in crowded cities and the failure to practice the very fine habits of personal hygiene familiar to the Greeks and the Romans, who in their sunny Mediterranean climate were accustomed to living out of doors and who knew a great deal about keeping the body clean and fit, contributed; the spread of pestilence, intensely dreaded, became a dominating fact in social life.

Is this state of affairs again to be linked up with the agricultural problem? In Chapter 7 we saw that the European agricultural system in the Middle Ages was not perfect; the treatment of animal wastes was crude and inadequate. Nevertheless it was good as far as it went. Perhaps that is where the weakness lay. The fault about European agriculture was that it did not go far enough, in the sense that it offered neither sufficient amounts of food nor sufficient varieties of food to those depending on it. The prevalence of scurvy for centuries is certainly to be traced to the absence of vegetables, many of which were not commonly grown until the sixteenth century, a fact to which importance may be attributed. But there was also a terrible lack of food, especially of fresh food, in the winter: and the freshness of food is of vital importance to health. Owing to the absence of roots, animals had to be killed, their meat had to be salted down; in fact, both animals and humans invariably starved during the winter months. No doubt the rich were well supplied -- we read of Gargantuan feasts, but the common people hardly knew how to exist. The results were exactly what we see in the East to-day: malnutrition, plagues and malarias (agues).

The change came with the seventeenth and eighteenth centuries. The introduction of additional crops, especially roots, saved Europe; it saved, in particular, the animal population. The increased dung must have added greatly to fertility. The result is to be traced in restored human health. Plagues and pestilences disappeared. Only smallpox, a dirt disease, lingered, to be conquered by medical means and attention to hygiene. Perhaps the food eaten by the various populations was at its best towards the end of these centuries.

From that time onwards various factors combined to prevent the continuation of good standards of nourishment. In our own country increase of population was accompanied by much pauperization; even had quality of food been available it could not have been bought by all. The upper and middle classes were, however, rather well fed during the best part of the nineteenth century and tended to indulge in that arrogance of the robust health outlook already noted. But this was not universal and there were many untoward signs. With the opening of our own era health began to be better understood, especially that of women and children. Then some improvement took place, largely the result of more sensible habits. But the upward movement has since declined disappointingly. The expectation of life has been lengthened, but illness, especially sub-acute forms of illness, are distressingly common.

We can once again presume the results of a depressed agriculture working on soils which have become notably depleted of their fertility during the last fifty years. The story of former centuries is being repeated to-day. Worn-out soils are bringing their inevitable concomitant of lack of stamina. Not the evils of our industrial life, but the insufficiency of our farming is at fault.

If the history of European health can thus be written in terms of European agriculture and more especially of European soil fertility, with graduations and changes which can to some extent be traced or at least surmised, can any deductions be made from the state of health prevalent elsewhere in the world? The facts are not simple, for the picture is too various. That exceeding poverty leads to malnutrition by reason of sheer insufficiency of food is obvious; many eat only once a day, are poorly clad, and ignorant of the first laws of health; among these malaria, plague, cholera, and hookworm find millions of victims. There is also starvation due to accidental failure of crops where climates are extreme and facilities for importing other food non-existent; but accidental failure of crops is not failure of agriculture. There is much prevalent disease in many parts of the world, combined with a quality of disease-resistance which seems to emerge in rather a startling way; we meet "islands" or even whole areas of abounding health and vigour, which impress themselves on our notice.

This is the most helpful line of inquiry. What is the explanation of these remarkable instances of almost ideal health shared by whole populations? Where are they to be found? The world owes it to Sir Robert McCarrison to have first found such a community. By drawing attention to the tribesmen of the Hunza valley on the North-West frontier of India he put the crown on an immense series of experiments and writings by which he had conclusively traced the very great differences in standards of health among the races of India to differences in their diets. (See Bibliography of 145 scientific papers by Sir Robert McCarrison in *The Medical Testament* issued by the County Palatine of Cheshire Local Medical and Panel Committees. Researches summed up in *Nutrition and National Health*, Cantor Lectures, Royal Society of Arts, 1936.) As medical officer of the Gilgit area Sir Robert McCarrison found these hillsmen the most vigorous people of the many vigorous tribes in North-West India. Their powers of endurance are amazing; they can walk the sixty miles to Gilgit, do their business, and return, thinking nothing of it. Some of our most common diseases are unknown to them; they scarcely know what ill health means. Their diet was found to consist of whole-wheat stone-ground flour, fresh milk and milk products, seed of pulse crops, vegetables and fruit.

There are other examples of admirable health in human society; the Eskimos and the islanders of Tristan da Cunha are both cited. Their diets are different, the Eskimos living principally on sea animals and sea birds, often raw, with a very scanty supply of vegetable matter or milk (a very restricted diet), the islanders on fish, potatoes, eggs, some milk, butter and a few vegetables. Both these diets differ materially from Hunza diet. The kind of food therefore does not seem to be the final criterion; nor is there similar preparation, for the tribesmen of the Hunza valley cook everything together in one pot, whereas the Tristan islanders eat only one food at a time.

The common factor as to food seems to be first its freshness and then its wholeness. The Eskimos compensate themselves for having to eat preserved food in the winter (they preserve fruits and blossoms in ice) by eating some raw food throughout the year, some organs of sea animals, and a great deal of fish oil. All three peoples eat their food whole, that is, they do not subtract germ or husk from grain, and, as already stated, they eat almost the whole of the animal. Primitive peoples have a great deal of empiric knowledge about what parts of an animal to eat, and assign specially important organs to pregnant or nursing women; they know which part of an animal will most quickly restore their strength if starving.

Important as this point may be, the matter does not end there. It only begins. We must go further back. What is common to these diets is that they are drawn from perfect agricultures. The agriculture of the Hunza valley surpasses in the faithfulness with which the laws of Nature are carried out that of any of the other Himalayan peoples; for hundreds of years every form of waste, including human wastes, has been composted and faithfully returned to the land. It is an additional point that the water used for irrigation is glacier water carrying finely divided silt, which may not improbably have the effect of renewing the mineral riches of the soil (Chapter 4).

It may seem odd to compare with this admirable cultivation what is done by the Eskimos or the Tristan islanders. The first cannot be said to have any agriculture; they draw their food almost exclusively, the Tristan islanders very largely, not from the land, but from the sea. It is just this which is so illuminating. The sea is, as the land ought to be, inexhaustible. Every form of waste to which it gives rise sinks back into it; the infinitesimal amounts we withdraw in the form of caught fish are obviously made good by the carry down of streams and rivers. We cannot interfere with the sea; we cannot mine it as we have the land. Sea food is, therefore, the safest of food, and, eaten fresh, can maintain a wonderful degree of health.

We may add to these examples and some others a new mass of evidence collected at first hand by an American dentist, Dr. Weston Price. This investigator undertook to examine the dental state of a number of peoples by personal investigations on the spot. He spent many years in collecting data and travelled many thousands of miles, his journeys taking him among the Swiss of the Loetschental valley, the inhabitants of the Outer Hebrides, the Eskimos, the North American Indians, Melanesian and Polynesian tribes of the Pacific Isles, many tribes of Africa, the Australian aborigines, the New Zealand Maoris, the Torres Strait islanders; finally he examined many thousands of skulls dating from the preColumbian period on the coast of South America and also such remnants of these ancient tribes as still linger in these parts. His work forms an overwhelming and most convincing array of facts, proving beyond a shadow of doubt the profound, direct and inescapable influence of diet on human health; even the hardiest sceptic must be impressed by the massive nature of the evidence assembled by this scientist. (Weston A. Price: *Nutrition and Physical Degeneration*. See Appendix B.) To sum up his work in a few lines is impossible. Two central facts stand out: that the dental state (and general health) of all these peoples so long as they kept to their primitive foods was magnificent; and that their physical degeneration, when they deserted these diets for imported trade-borne foods, was of almost unbelievable rapidity. The book makes tragic reading, for in most cases the change over has been very recent and two generations exist side by side, the older presenting perfect teeth and facial formation, the younger with ruined teeth and miserable facial formation; as might be expected, other evils accompany these.

The diets examined, though very varied, agree absolutely with the indications given in the cases of the tribesmen of the Hunza valley, Eskimos (whom Dr. Price also examined) and the Tristan islanders; they were very largely drawn from the sea. Great efforts were made sometimes to obtain sea food, especially for the young mothers; great stress was laid on the shell fish; sea-weeds were eaten. Where diets were mixed, grains were consumed whole. Thus of the Polynesian populations of various islands of the Pacific, the author states: "in all of the groups living on native foods with liberal intake of the animal life of the sea, the health of the gums was generally excellent. When, however, the sea foods were quite limited in the dietary, heavy deposits formed (on the teeth) and often were associated with a marked destruction of the supporting tissues with gingival infection." In contrast may be cited the non-sea diet of the Loetschental valley people; here there were ample animal wastes in the soil, for almost every household had goats or cows or both, and "great care was used to carry back to the soil all of the enrichment". The result was a splendid standard of health, which sank rapidly with the introduction of white bread and other partially depleted foods in 1931.

One great lesson that emerges is that the food we eat should be fresh food, whole food, and *drawn from a source which is itself whole*, that is, which has not been impoverished, depleted or exhausted. In the case of sea foods, the source can never be depleted; that is why these foods are so safe as part dietary, a fact which many primitive peoples seem to have grasped. In the case of land foods, there is no such assurance; but if wholeness can be maintained, then abounding health follows. This wholeness of the land we call fertility.

We see where the agriculture of China falls into place. We have called that agriculture perfect; we may now look at its results in terms of human health. It has produced a race whose staying power outlasts every calamity. On his minute plot the Chinese peasant thrives; he is always cheerful, a point which has frequently been noted; his health is patent and vigorous. True, there are frightful epidemics and terrible diseases are known. These are almost always to be traced to the action of some climatic factor, either flood bringing famine, or else a permanent lack of good hygiene bringing the diseases associated with dirt; there is a bad record shown here. Yet all in all the population stands up even against this, so that it has been wittily said that only the Chinese peasant could survive the diseases of China.

Such being the factors in the situation, we begin to see why human society offers such a strangely variegated view. Each factor counts, but each is found present or absent to a very different extent among the communities of which we have knowledge. We can, however, broadly say that questions of health are principally questions of food: but food means agriculture and agriculture means the soil.

Are there in this field of human health any examples comparable to those we described when discussing animal health, namely, cases showing groups of men and women previously suffering from debility or disease now brought up to outstanding health as a consequence of consuming healthy food grown on fertile soil?. The World War has greatly interrupted what was being done in this direction, but some such examples are available. They are more in the nature of indications than of accumulated proof, but time will add to them; they agree so well in every particular with what we know about the other sections of the Wheel of Life that those of us who by now are convinced of the truth of what we have been stating will hardly ask for more.

The first example was recently brought to the notice of our own House of Lords in a much quoted debate initiated by the advocates of more healthy food for the people. It was stated that the opening up of the Copper Belt in Northern Rhodesia, in a district previously depopulated by sleeping sickness, malaria, and all the range of tropical diseases, had been made practicable soon after 1925 by systematic methods of feeding the workers with quality foods. The whole of the arrangements was "based on the health of the food". The apparently hopeless task of making possible a working life in an impossible climate was triumphantly accomplished; the workers were kept healthy because they received "food grown on rich humus soil with plenty of life in it". (Lord Geddes in the House of Lords, October 26, 1943.) Three other examples come from schools: St. Martin's School, Sidmouth, England; St. Columba's College, Rathfarnham, Eire; and Mount Albert Grammar School, Auckland, New Zealand. In all these cases there was a rapid and quite obvious improvement in child health following on the consumption of properly grown fruit and vegetables; of the school at Sidmouth it is stated that lads who came as weaklings left healthy and robust; they never looked back in point of health, and became fitted to play a good part in the world crusade of the war. Here the soil had been put into a superlative state of fertility, and, as might be expected, the crops were immune from insect pests and diseases. (Details of these and further cases in Howard: *The Soil and Health -- Farming and Gardening for Health or Disease*, pp. 175-7.)

The most striking example is drawn from the Far East, from results obtained in the short space of two years. Dr. Scharff, chief health officer at Singapore, between 1940 and 1942 watched the health of the five hundred coolies employed by his department in various parts of the island improve out of all knowledge as the direct result of his campaign to induce them to grow and eat their own vegetables cultivated with compost. The effects were patent; "an oasis of good health" was established. "Debility and sickness," writes Dr. Scharff, "were 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 of 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" (text of letter from Dr. Scharff to Dr. Lionel Picton in Howard, op. cit., pp. 171-2). This case is of particular interest because the speaker is an exponent of the practice of composting human nightsoil. Thus the fine health of the Singapore coolies was made to rest on a very significant carrying out of the Law of Return.

We thus come back to our basic principles. We, a part of the natural round, must obey the laws of the round; we are bound to the turning of the Wheel of Life. Persistent refusal to conform to the most important of Nature's dictates is sure to bring disaster. Yet if we are bound to obedience, we can also claim all the privileges which Nature bestows upon her creatures; we, as well as plants and animals, can fall back on that immense system of reserves which is such an integral part of her working. Thus we enjoy great freedom; there is an extraordinary elasticity in Nature of which we can take advantage, and as long as we do not depart too widely from what she lays down, we survive in good health and good spirits.

We can do almost what we will provided we ensure the protein chain. If this is guarded, if the proper synthesis and the smooth transmission of the substance which holds life is secured by fertility in the soil, we may feel certain that the precious endowment of good health will be handed on to our crops, our animals and ourselves. But, if we neglect, or even worse, if we interfere with the chain, if we allow our soils to run down or whip them up mercilessly by improper means, then not only may we suspect, but we shall prove in our own persons, that a weakness has been set up at the source which Nature will take care to carry forward for our punishment to the end.

This cannot but happen if we persist in errors, of which there have already been too many. The modern pursuit of quantity of produce at all costs has been one. The pursuit is bound up with the profit motive, but it is also engendered by fear. It becomes a dire temptation, then a source of false pride. There is a curious fascination in the aim of heavier and heavier tonnages of wheat, more and more last half-pints of milk, batteries of hens, and eggs reckoned by the million gross; yet it is not quantity that we truly lack. Over-specialization, what is known as monocrop farming, pursued in a reckless way, has been another mistake, bringing an unhappy divorce between the plant and the animal in defiance of one of the first laws of Nature. But there has also been a general neglect and carelessness about the soil, a total indifference to contouring, an excessive destruction of the natural tree canopy, insufficient attention to aeration, and many other follies. These evils have been insidious; they have seldom been deliberate; they have been forced on the individual cultivator, who, indeed, has frequently had high authority for what he did.

Not the highest of all: not Nature's authority. She has spoken with a very different voice. She does not promise this or that, the heavier sack or the fuller pail; these will come, but they have to be earned, always by obedience. Her verdicts are two only: health and disease. Those fungi, those viruses, those plagues and pestilences that infect our crops and kill our animals, that debility, those ailments that spoil our lives, what are they but her appointed censors, her sharp weapons to warn us that the Wheel of Life is not to be deflected, but must be watched, understood and followed?

That perfect health, uninterrupted from first to last, will ever be the portion of all living organisms is not, indeed, possible; disease, we must repeat for the last time, has a place in the revolving of the great Wheel. But the part it has to play is meant to be restricted; bow often have we declared that there should be enormously more health than disease in this world? Life was given us as a function to fulfill, not as a state to be suffered.

The green carpet is our greatest natural inheritance, and it is our true destiny to understand it, use it, and enjoy it.

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The Earth's Green Carpet

By Louise E. Howard

Epilogue

In our survey we have made many references to Nature, to which we have assigned a portion of unquestioned dominion in the world of physical phenomena, assuming by the expression "Nature" an orderly system proceeding on laws which are neither capricious nor finally beyond our comprehension.

To this system we owe obedience. This also we have stressed, indeed we have attached much importance to action in conformity with natural laws. The emphasis thus laid has been deliberate. Let us feel it has a needed corrective of some past arrogance in our human history. The great wealth which a few generations of mankind have been enjoying has been derived from the discovery of natural accumulations, of great stores of mineral substances such as coal and oil; to these have since been added the beginnings of a mastery over the gases and conditions of the atmosphere. For a century or more man's conquest of matter has been vaunted as a favourite theme; new vistas are alleged to have been opened: a new heaven has seemed at hand.

This paradise is a delusion and a terrible moral conflict has arisen among us. As fresh material discoveries are made doubts as to their ultimate validity become more and more insistent. Whither does all this tend? The joys which we promised ourselves and which seemed within our grasp are a deception; as we advance they recede. They prove useless because they have been derived from two unworthy premises: ignorance and exploitation. The idea that we can ultimately at will master the natural world shows an inability to grasp the character of that world. The suggestion that we are entitled to exhaust natural riches is robbery. Nor is our boasted dominion anything but limited. It breaks down when we approach what is alive. If sometimes we take upon ourselves to terminate life, we must acknowledge that we are unable to create it. Mastery here is partial, irregular and often ineffective. In no way do we finally alter the immense order of Nature, who in her ceaseless round initiates her own beginnings and decides also on her own moments of decease.

What then shall we do? We can have recourse to one thought only: recall the familiar fact that we are at one and the same time part of the natural world and also the only category of created things endowed with the capacity to apprehend it; we are in creation and outside it. This gives us a peculiar power from which we can derive all we need. We can and may -- indeed we must -- first understand the system of which we are a part; because we are a part we must obey. But because we can apprehend we may apply our understanding to our profit. It is permitted to us to use Nature and to use her largely but neither to alter nor command her.

There is in reality no limit to our use if we know what are the laws we have to follow. Our application of principles may be bold in the extreme. What is more astonishing than our selection of similar plants to grow in the same area at the same time? It runs counter to one of the greatest principles of Nature. Yet we can carry it to a successful and a safe conclusion provided that we know how to restore the balance of the mixed existences that Nature loves. What is bolder than the pruning of the tree? Yet we yearly undertake this, confident in the experience which tells us of Nature's insistent desire to propagate the species, which will induce the heavier fruitage and compensate the cutting. We dig and delve and turn the soil in a way which Nature scarcely permits to her own creatures, but it is in order to lead more ample supplies of air and moisture towards the growing root. We tame and confine our animals, but it is in order to take advantage of the ineradicable instinct which causes them to procreate their young and care for them. Nothing that we do is too bold provided it is done in intelligent confirmity with law.

It is proper to admit that our decisions as to practice can never be easy. Nature is not concerned to give us simple lessons. Therefore it must always be our part to keep a careful watch on what we undertake and to abide by any test which offers us the means of a just and reasonable judgment. Of all the tests the best is that of fertility of the soil. If what we do maintains it, we may be sure that we are not astray; if we appear to be destroying it even by a little, then we are on a dangerous decline. The earth's fertility, the power that maintains the springing of the green carpet, is the one essential to the conservation of life. Only if the soil is fertile can the green leaf permanently exercise its unique power of seizing on the energy of sunlight and turning it to use. The maintenance of this continuing capacity of green living things so far outweighs any loss of past accumulations of dead matter such as coal and oil as to make the exhaustion of such mineral stores a matter of indifference.

What is the future outlook? Contrary to the prevailing mood of pessimism we may confidently answer that it is a good one. There are no past mistakes that we have made that can not be repaired; so wide is Nature's power, so boundless her generosity, she can and will help us; even where we have spread a desert the green carpet can be made to smile again.

Far more than this is promised. We are nowhere near our final probing into Nature's wealth. We have scarcely begun to assume our great inheritance. Plenty awaits us of which we have not dreamed. The possibilities of intensifying our cultivation are almost endless. If every inch of our present neglected soils were brought to the fertility of a Chinese garden, if we could recall Inca agriculture or equal the wealth of the Hunza valley, this would be a mere beginning; we could thereafter so lay out the kindly earth that, after leaving ample space for rural pleasure and urban recreation, we could provide every natural material and every natural luxury that the heart of man could wish. An abundance of food, drink, shelter, clothing is lying at our feet. If we chose to put into our use of the green carpet one-half of the energy and knowledge now dissipated for wasteful ends, the garden of Eden would be round us once again.

Into this garden we could enter as more worthy and as more amiable inhabitants. The fertility which we should be conserving in our soils would be passed on as health into our crops, our animals and ourselves; health would bring an end to some contentiousness seeing that the well-fed creature is a happy one. We will abstain from the pretence that all would be set right. The world would be as it is now; our natures much the same. But we should have abolished one fear, the fear of hunger; we should have left behind a trail of weaknesses and be fitted to enjoy the beauties of a world which we had ourselves made more lovely.

In the hard projects of agriculture common sense, experience, and facts are the only things that count. It is on these that our thesis has been based. The day will come when what is here set forth will be accepted as a very simple contribution to what each human being ought to know.

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The Earth's Green Carpet

By Louise E. Howard

Appendix A
The Indore Process and its Evolution

As was explained in the text of this book composting is no new idea; in addition to what is done by the Chinese many primitive peoples make some sort of compost to put on their land; their methods and success vary. The old gardeners' practice in Europe of saving the leaf-fall and making it up into heaps is something of the kind; it is very slow, for the heap takes two years to mature, it lacks the lignified cellulose supplied by the twigs and branches and above all it lacks the animal element. True composting can be said to be achieved only when the vegetable and animal elements are combined in correct proportions and have been subjected to the influence of moisture and of air.

The Indore Process, of which a general description was given in Chapter 7, owes its origin to the conviction which gradually impressed itself on the mind of its inventor, Sir Albert Howard, during the years of his career as an officer in the Department of Agriculture of the Imperial Government of India, that there was little point in offering to the Indian cultivator improved varieties of the crops to be grown unless one initial difficulty could be solved. Owing to the habit of burning three-fourths of the cow-dung it was impossible to fertilize the fields up to the point where they could grow the improved varieties with any success; on the contrary, it was more than likely that such improved varieties would only tend unduly to exhaust the soil. In looking for the solution of this problem it seemed obvious to try out methods which had been known in China for over four thousand years. The investigations into the making and efforts of compost, the temperature, chemical, and biological tests were carried on from time to time for many years by Sir Albert Howard himself and by his wife and personal assistant, Gabrielle Howard; they were finally completed at Indore, where Mr. Yeshwant Wad cooperated in the chemical work. The result was the Indore Process, so named in acknowledgement of the generosity of the Maharajah Holkar and the Durbar of the State of Indore, who provided the site for the Institute where the final stages of the work were carried out. It is not too much to say that the Indore Process is the result of twenty-six years' scientific investigation implying an expenditure of £100,000 at three different Experiment Stations, Pusa, Quetta, and Indore.

The book describing this work, which was published in 1931 under the title *The Waste Products of Agriculture: their Utilization as Humus,* was addressed principally to the Indian public. It did not occur to the inventor of the Process that the principles worked out by him would have a world-wide application. The facts about the deterioration of soils were not at that time so well known; the phenomenon known as the dust bowl did not appear in North America in any marked degree until 1932 or 1933 and only became disastrous in 1934 and 1935. It was in the course of a holiday voyage round Africa in 1932-3 that a visit to one of Colonel Grogan's estates in Kenya Colony first suggested a wider field of work. Further contacts with others interested confirmed a decision to abandon all competing interests and to apply the leisure of retirement to a campaign for encouraging the Process.

This almost at once began to widen out and to embrace far more profound problems. The whole meaning and basis of soil fertility seemed to call for reflection and comment; ideas were rapidly evolved which threw a flood of light both on previous work and on the many current experiences which were being communicated from all parts of the world. Eventually contact with the Local Medical and Panel Committee of the County Palatine of Cheshire, which, under the leadership of Drs. Kerr and Picton, did such notable pioneering work in the stand taken in the well-known *Medical Testament*, confirmed in the field of human health ideas which had been tested out in the Indian days on many kinds of crops and to some extent on animals. The generous interest of the late Sir Bernard Greenwell provided a welcome addition of facts in the latter field and also in some other directions, to be followed by co-operation and help most abundantly and willingly provided by a number of other supporters, of whom the great tea industry firms were among the first. Within five years of its start one firm was already in 1938 making not less than 150,000 tons of compost annually.

The campaign now began to take on the aspect of a call for a revolution in farming. The prevailing treatment both of soils and of animals came under discussion and was questioned. Every new idea was forthwith tried out on the land by some pioneer, and the invariable success attending these experiments proved a principal factor in uniting in spirit a number of forward-looking individuals, who practice what they preach under the title of organic farming; of this school 'there are many distinguished exponents.

The campaign evoked from the outset the opposition of most of the official Experiment Stations and Agricultural Colleges, who, with a few honourable exceptions, did not hesitate to pour on it ridicule and contempt; in view of the fact that one of the principal contentions of the farmers of the new school was complete disbelief in artificial manures or in poison sprays the opposition of these interests also could scarcely be in doubt. In spite of this, and in spite of the absence of any official support, funds, or authority, the spread of the new doctrines was amazing. The Indore Process itself is now known and practiced in the following countries and probably in others not named: England, Scotland,

and Northern Ireland; Eire; Canada, Australia, New Zealand, South Africa; Rhodesia, Nyasaland, Kenya, Tanganyika, Uganda, West Africa; the West Indies; India; Ceylon; Malaya; Palestine; Italy; the United States of America; Mexico, Costa Rica, Guatemala, Chile, Peru, Salvador, Argentine; and was used by some of our armed forces.

Perhaps the Process has been most slowly adopted in Great Britian, where the experience of two wars has made the population nervous and inclined to be too anxious to follow official authority. The popularity of composting has, however, greatly spread in the last few years among allotment holders and small gardeners, who have gladly welcomed the opportunity of growing their own quality food. Among these the New Zealand box, which is extremely cheap and easy to make and which seems ideally adapted to the needs of such small cultivators, has had a great success. But a number of owners of large estates have also been most anxious to apply the principles of the Process. Their combined efforts together with the co-operation of one or two leading firms making agricultural machinery bid fair to solve the question of suitable machines for the assembling, turning, and spreading of the material, but even without machinery and with our highly paid workers composting can be made to pay handsomely, as has been proved by actual example. An ingenious use of gravity has also been tried to allow the muck needed in composting to drop from one level to another and to permit of the finished material being collected in carts; where large-scale work is to be done this might be a great advantage and only calls for thought in the lay-out. Composting has also come to stay in glass-house work, where it has had the inestimable advantage of eliminating disease. In general, the original Process has been modified in the direction of simplicity. A little experience is needed; many small cultivators begin by making their heaps much too small and much too tight. Full directions for making compost and for constructing the New Zealand box are printed at the end of the present Appendix.

The Process has proved itself completely adaptable to every type of cultivation and every climate, which shows that the principles on which it is based must be sound. At an early stage it was shown to be capable of dealing with the most refractory material. Major Layzell, manager of the Taveta estate of Colonel Grogan, was able in 1935 to compost the unpleasant wastes from sisal, which are of such a nature as to be a veritable nuisance to the countryside; the dumps of solid matter putrefy and smell for miles; the so-called "soup" or fluid waste contaminates the streams and kills the fish; both these evils disappear with composting. Similarly Mr. Dymond, chief chemist to the South African Sugar Company in Natal, succeeded in 1938 in composting the leaves of sugar cane, which are most difficult to break down and may be described as armour-plated. There are other directions in which composting may help to deal with well-known difficulties; thus the composting of water-hyacinth in Bengal, as it was successfully carried out by Mr. Fairlie Watson, superintendent of the governor's estates, Bengal, shows what use could be made of something which up till now has been listed as a noxious weed, a deadly menace to the waterways of India; the composting of water-weeds is a subject to which little thought has been given, but it opens up very great possibilities in view of the fact that such weeds are the perfect agents for catching and saving for us the rich dissolved food materials either in natural streams or in sewage effluent.

In one respect the Indore Process differs from Chinese methods -- it invariably, if properly made, induces a very high temperature in the mass composted, which suffices to kill most weed seeds and all pathogenic germs; the margin of safety is ample. This, of course, is a very important consideration. It has an obvious bearing on the composting of urban wastes, the return of which to the land becomes an even more urgent problem. Their loss, which began about a century ago, cannot but greatly impoverish our soils. The problem becomes even more acute when we realize what an immense shrinkage there has been since 1910 in the supply of animal manure as a result of the substitution of motor for horse-drawn transport.

There are two forms of urban waste, dustbin refuse and nightsoil or sewage. In most countries a beginning could at once be made by the return to the land of the former. In our own country there exist very rich accumulations from the past in the shape of controlled tips. These have been built of unsorted rubbish and have been sealed with a layer of soil or ashes; the rubbish has not been incinerated and its organic content has therefore not been destroyed. On the contrary, owing to the supply of air which remains with the rubbish -- and because of its irregular nature there is ample of this -- this organic content soon becomes completely oxygenized and broken down; it is therefore waiting as rich fertilizing material, which only has to be roughly screened to be of immediate use. The careful investigations of Messrs. B. B. Jones and F. Owen at Wythenshawe in 1932 (*Some Notes on the Scientific Aspects of Controlled Tipping,* published by the City of Manchester, 1934), showed this material to be free of pathogenic germs; its restoration to our fields would do much to restore them to a good state. Current refuse, which is estimated at about thirteen million tons a year, could thereafter be made available; a plant constructed by the Borough of Southwark in South London has been particularly successful. In 1939 the all-in cost of separation, pulverization, and application to the land of the material in the controlled tips was estimated at 7s. 6d. per ton (letter of Sir Albert Howard to *The Times* of Sept. 5, 1939).

Neither should the disposal of human nightsoil in a way to benefit agriculture prove difficult. Composting of this material together with vegetable refuse is possible in long pits on perfectly hygenic methods; the resulting manure is pathogenic-free and most valuable. Not only has this been proved by careful experiment (Jackson and Wad at Indore, Dr. Scharff at Singapore and others), but one country, South Africa, has begun to carry out such work on an extensive scale. After pioneering essays done by Mr. van Vuren at Ficksburg the authorities of the Union Government were so impressed that they initiated a training scheme with Mr. van Vuren in charge. The result has been the adoption of composting schemes for this material by over one hundred municipalities serving two-thirds of the total urban population in the Union and including such important centres as Cape Town, Pretoria, Potchefstroom, Johannesburg, Ficksburg, Bloemfontein, Kimberley, Durban, Stellenbosch and Pietermaritzburg. The end product finds a ready sale and will do much to restore the phosphate-exhausted soils of the Union. The whole of this most interesting, new departure, which might well be copied by other countries, has taken place since 1939. Such a system could be inaugurated at a large number of centres and would confer the most distinct benefits on urban communities as well as on the country-side. Details of Mr. van Vuren's work in Howard: *The Soil and Health (Farming and Gardening for Health or Disease)*, Appendix C, The Utilization of Municipal Wastes in South Africa, by Mr. van Vuren himself; for some previous work see Howard: *An Agricultural Testament*, Appendix C, pp. 235-42, "The Manufacture of Humus from Wastes of the Town and the Village".

Where water-borne sewage has already been undertaken or where the size of the urban centre makes it imperative, the question arises as to how to deal with such sewage. Treatment is already advanced, it being widely recognized that to run it off crude into rivers or streams is a major mistake, though cities well placed in this respect are still tempted to indulge in this faulty practice as the easiest; when they do, the whole contents are lost forever and there is also the continued danger of poisoning waters, especially when not under the immediate influence of strong tides. Elsewhere the sewage is treated by modern processes of activation, from which the solid matter emerges as sludge, an odourless unobjectionable powder when dried, which forms a useful fertilizer. This should be bagged and made available to the allotment holder in small quantities, to whom it would be quite invaluable in view of the difficulty of obtaining animal manure, but few municipalities will take this trouble and much more public pressure is needed.

When the sludge has been disposed of there remains the effluent. The accepted method of dealing with this is to run it into so-called sewage farms; alternatively it is run out to sea and anything it contains is lost. There is here a great need of experimental work, for it would seem likely that a far better principle would be to stimulate a growth of water plants, which would automatically clear the effluent of all its most valuable mineral contents and incorporate them into their own structure; from time to time such water plant growth could be cut and then composted; in this way practically nothing would be lost to us, and the effluent, being almost pure water, could be run off anywhere. This idea still awaits a proper trial.

There is also an alternative principle. This is not to activate but to use a reduction process. Under anaerobic conditions methane and carbon dioxide are produced and almost none of the combined nitrogen is converted into the gaseous state and so lost to the system. The final result is most advantageous; the constant supply of methane produced can help our fuel problem; the resulting sludge is deprived of much of its colloidal and deleterious matter and, after drying, can be safely added to the soil or to the compost heap.

The general conclusion is that this is a problem on which the public has very well-defined rights and also duties; to return wastes to the soil is a debt which the city owes to the countryside. It is no longer possible to argue that this cannot be done; the experience of

South Africa, where in less than ten years the whole business was handled in a new way, shows that inititative and a little courage are all that are needed. Even the wastes of the largest cities are capable of recovery and steps should be taken without further delay to see that this is done.

One word of warning is necessary, and this applies to the whole subject of composting rather than merely to the disposal of sewage. Composting has become so popular that the inevitable has happened -- the hope of gain and the desire for notoriety have both crept in. A number of patents have been taken out or, alternatively, secret preparations are being advocated and sold, all stated to be an aid to the making of the best compost; in some cases there has been a real self-delusion and the advocates are quite sincere in what they do. Nevertheless, it cannot be too clearly stated that in the manifold living chemistry of the compost heap neither the claim to secrecy nor the claim to special preparations can for a moment be sustained; the intricacy of the natural processes is far too great to be tied down in any such way and claims in this direction can only be described as misleading. The cultivator will be well advised to make his own compost without such so-called aids, the principles of compost-making cannot conceivably be either patented or concealed, for they are merely a manifestation of natural law, easily understood by all.

Practical Instructions for Making Compost by the Indore Process

1. Composting in Large Gardens

Materials

The first requirement is "organic wastes", that is, plant residues: weeds, leaves, old straw and hay, bracken, reeds, seaweed, hedge trimmings, etc. Spoiled paper, worn-out clothing, leather and sacking can also be added after previous soaking in water. All green material should be partly withered. Hardy woody material should be cut into short lengths and crushed where possible by, for example, wheel traffic. Anything very resistant can be transferred from heap to heap if the first is not enough to break it down.

The second requirement for the compost heap is animal manure, from horses, cattle, sheep, pigs, rabbits or poultry. Nothing is better than freshly used nightsoil for this purpose which, if the composting be well done and the nightsoll be immediately covered with humus, is safe and entirely without offence. Dried sewage sludge can also be used.

The third requirement is earth, if possible mixed with ground limestone in the form of grit, wood ashes, or preferably a mixture of all three. The earth, etc., is needed as a neutralizing agent to keep down acidity.

The fourth requirement is water. In general, rain will supply this need (in fact it may be said that protection from rain is more important in Great Britian than the provision of water, although there are occasions when it must be added). The heap must not be too wet, the consistency of a squeezed sponge being aimed at. Liquid manure (for instance, bedroom stops or drainage from a pig cote) is of the very highest value.

During the early stages of decomposition air is required in large quantities by the fungi and germs in the heap. This is got by diffusion from the atmosphere, so the heap must be made loose. Later, after the fungous stage is over and the material has crumbled and darkened, the heap has reached a stage where the fermentation goes on without much air. The germs then obtain some of their oxygen from the decomposing material itself.

Making Large Compost Heaps

Composition of the Heap. Make oblong heaps upon earth, *NOT* concrete. If possible, a bottom should be made in a similar manner to that of a haystack. Hedge trimmings, bush fruit prunings or other materials which will act as an open base are suitable. This assists aeration. On this base the heap is built. It consists of an intimate mixture of 3 or 4 parts by volume of mixed vegetable wastes, 1 part by volume of animal manure, and a good sprinkling of the neutralizing agent made up of equal volumes of earth and fine limestone grit. (Where wood ashes are available, these may replace a portion of the limestone grit.) *By mixing the materials as the heap is assembled, the fermentation is assisted and much labour in turning is avoided.* Continue the building of the heap till a height of 4 to 5 feet is reached. It will sink later to about 3 feet. A final layer of manure 2 to 3 inches thick followed by a sprinkling of mixed earth and limestone grit, which should completely cover the manure, will complete each section of the heap.

In districts of heavy rainfall it is always advisable to arrange for the finishing layers to form a double slope.

In most parts of our island a temporary covering IS ESSENTIAL to protect the heap against excessive rain. Boughs or poles should be laid across the heap to raise the covering.

Size of the Heap. The minimum size for a heap is 12 ft. x 5 ft. x 4 ft. high. With any size smaller, the ratio of cooling surface to volume is too great. In such cases use the New Zealand box described below.

When making the heap always build it in sections of about 4 feet long and complete each section to the full height before beginning the next. The second section is then built close up to the first and completed before beginning the third and so on till the full length of the heap is reached. In this way no time is lost -- fermentation in each completed section begins at once. In addition, each section protects its neighbour and the heat is conserved. Space must be allowed for turning the heap.

Supply of Air. It is very important that the heap should be made as loose as possible in order to permit of copious aeration, and care should be taken not to step on the heap whilst building.

Aeration can be greatly assisted by making vertical holes in the heap by means of a rod or crowbar. Some people stand a rod upright first and make the section of the heap around it. The ventilation holes should be made 4 inches wide by working the rod to and fro. The holes should be 3 feet apart.

Turning the Heap. Provided due care is taken when assembling the heap to make a thorough mixture of the materials, only one turn will be needed. This should be done when the intense fermentation (which sets in at the beginning and when temperatures round 150° F. are reached) begins to subdue and the heap begins to cool. This will occur about three weeks after assembling, by which time the inside of the heap has turned white due to the development of fungus growth.

At the end of three weeks or so the heap is turned from one end, care being taken to bring the outside to the inside of the remade heap. Provided everything has gone well, no holes need be made in the turned heap. The heap can now be left to mature.

Completion, Position of Heap, and General Management. Three months after the process began the material is ready for application to the land. It consists of a finely divided product of which about 80 per cent will pass through a sieve of six meshes to the inch.

Protection against excessive rain has already been mentioned. The opposite possibility of dryness must be watched for and, if rain be insufficient, water must be added. This must not be sluiced on to the heap with a bucket but sprayed either by a hose with a nozzle or from a can with a rose. It has already been mentioned that the material should have sufficient moisture to give it the consistency of a squeezed sponge. That is the guide to which the maker should work. It is impossible to lay down a hard and fast rule concerning either the protection of the heap from rain or the addition of water in the absence of rain. The heap has life and must be looked after like all living things.

Once the technique of compost making has been mastered and a satisfactory product has been obtained, it is possible to save a certain amount of watering by using fresh green material in the heap. But care must be taken not to overdo this, otherwise silage and not compost will result.

If a sheltered site can be chosen facing south and with a wind-break from the north, so much the better. This applies particularly where the heaps are small and for these smaller heaps, where possible, protection should be given on three sides by means of walls or hedges; but the heap must never be banked up against a wall. The system by which mutual protection is given by old and new heaps should also be used wherever possible.

2. Composting in Small Gardens

In small gardens where the quantity of wastes is considerable 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 which work best at temperatures ranging from 150 to 90 deg. F., when the heap is moist and when there is ample oxygen.

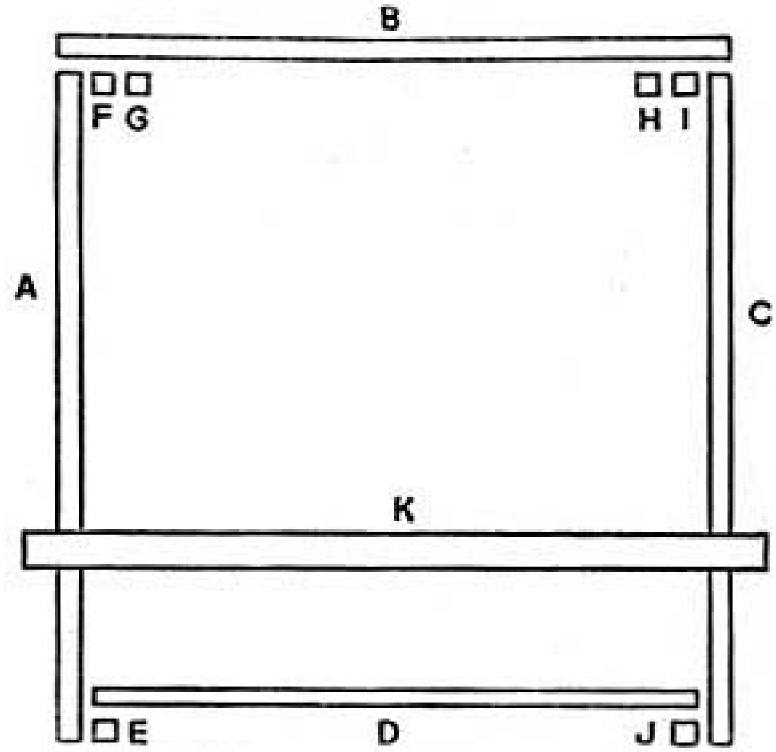
These difficulties can be overcome by the use of a pair of New Zealand boxes. This box was devised by the New Zealand Humic Compost Club for use in the gardens of New Zealand and works well in this country. A suitable box can be made as follows:

Materials Required for Each Box. Six 3 ft. 3 in. lengths of 2 in. x 2 in. for uprights. Twenty-four 4 ft. lengths of 6 in. x 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 cresote should not be used.

The box (see diagram), 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 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 L. The front D is made up of loose boards, 6 in. x I 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, 2 in. x 1-1/2 in., with two wooden blocks, 3 in. x 2 in. x 1-1/2 in., as indicated in the ground plan below of the box and the elevation of the bar K.

When the box has to be removed to a new site, remove the loose boards and the four bolts, and re-erect the box in a fresh place.

The New Zealand Compost Box



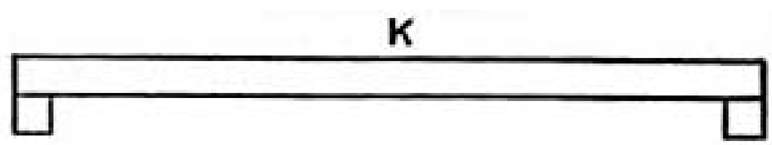
Plan of box showing bar in position.

A, B, and 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).

E, F, G, H, I, and J are the uprights (each 3 ft. 3 in. long).

K is the bar, provided with a block at each end, to sit on top of the sides A and C to stop them spreading.



The bar in section.

Making the Heap. Having made the two boxes, throw your mixed vegetable material (broken or cut if necessary into lengths a few inches long) into one of them as it comes to hand, together with one-third the volume of manure and a little earth and limestone grit, mixing the wastes, manure, soil and grit as the box is filled. The proportion by volume of mixed vegetable wastes to manure should be 3 or 4 to 1. 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 sewage sludge, 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 inches 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.

Next water this mixed material 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 box will take no more material. Rain (which is a saturated solution of oxygen) should be used wherever possible instead of the rose to keep the contents of the box moist.

After the box is half full, make and maintain one vertical ventilation hole in the middle by thrusting a light crowbar or stout garden stake into the heap and working it from side to side. The hole 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 box. This ought not to happen and is generally caused by over-watering or want of attention to the details of filling the box. If it occurs, the box should be emptied at once and then refilled. (2) Fermentation may slow down for want of moisture, when the mass should be watered. Experience will teach how much water should be added when filling the box.

Turning the Compost. Provided due care is taken in filling the box, no turning is necessary. After four weeks or so the contents should be moved into the empty box, watered if needed to keep damp, and then allowed to ripen for a month or six weeks. No ventilation vents are needed in the second box. The compost, which weighs about three-quarters of 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 dried in the sun and kept in an open shed.

3. Composting on the Farm

The principles set out above for compost making in the garden apply equally to the farm. The only difference is that on the farm the heaps are very much larger and much of the work can be done by a tractor-driven muck-shifting machine, of which several types are on the market. Every farmer, however, and those members of his labour force engaged in compost making would do well to begin operations in their gardens and to master thoroughly the above-described technique essential for the making of really high-quality compost. They can then apply their first-hand experience to the assembly and management of the large mechanized heap, always remembering that the heap is alive, that the work of compost making is being done for them by living organisms-moulds and microbeswhich require just as much care, thought, and management as their livestock. In this task all concerned will do well to forget everything they have ever learned about chemistry and to bear in mind that *the principles underlying composting are biological* *and not chemical.*

Mixing the Raw Materials. As will be evident from the above, one of the great labour-saving devices in compost making is to mix the materials -- vegetable and animal wastes with a little soil and limestone grit -- under the livestock in the cowsheds, loose boxes, piggeries, and so forth. This reduces much of the expense involved in turning the heaps. Further, the treading of the animals helps to fracture the outer covering of straw which was designed by Nature to protect the crops from the inroads of pests -- mostly fungi and insects; for the compost heap none of the litter needs any protection from fungi -- the sooner this protection is destroyed, the quicker the fungi can convert the material into humus. The bedding of the livestock should be as ample as possible, so that all the litter can be well broken up by treading and thoroughly impregnated with urine and mixed with dung. As the urine of the animals is one of the chief foods of the compost-making organisms, it must not be allowed to run to waste but must be completely absorbed on the floor as it falls from the animals by such materials as shavings, peat, and sawdust, as well as straw.

To keep down the acidity in the compost heap a mixture of equal parts of limestone grit and soil should be scattered on the new bedding after this is laid down. This does two things: (1) the compost heap is kept sweet; (2) a small continuous dressing of limestone constantly reaches the land and helps to lower its acidity.

The soiled bedding is now ready for the compost heap, to which it should be transferred as quickly and as cheaply as possible. The exact methods used will depend on circumstances such as the -lay-out of the buildings and the position and size of the composting area. One difficulty, which can only be removed by time and experience, arises from the fact that when the present farm buildings were designed, labour was cheap and abundant and the importance of compost making was not understood. But as time goes on, simple and cheap modifications of the existing lay-out to assist in humus manufacture are certain to be made.

The compost heaps should be assembled in complete sections, each about 4 ft. wide and 4 to 5 ft. high, and ventilation holes should be made about 3 ft. apart. The second section should be made close to the first and completed with ventilation holes before beginning the third and so on till the heap is finished.

The heap can be turned by the machine once or twice as may be necessary. The finished compost can be loaded into carts or manure distributors by the same implement.

On sloping land it is sometimes possible to save an enormous amount of work by the utilization of the force of gravity. When the cowsheds are built on the levelled top of a small hill, a composting terrace can be excavated at a lower level so that the soiled bedding is never lifted but allowed to fall from the floor of the cowshed to the composting terrace below. Here the compost heaps are made and turned by hand labour. A third terrace below the second is metalled like a road for the carts or manure distributors which can be filled without lifting the finished compost. This labour-saving system has been adopted with great success by a retired officer of the army in Tanganyika. There the raw material for composting makes two descents on the way to the field -- the first from the cowsheds to the composting terrace, the second from this terrace into the carts. As much of Great Britian is hilly, it may be possible here and there to adapt this simple gravitational method of composting to local conditions and to save an enormous amount of heavy work.

Another labour-saving method is to keep the animals in two open yards, each about 100 yards long and 20 wide (enclosed by a suitable wire fence), on either side of a sunken road so that the finished compost can be forked into the carts without any lifting. These long yards are used alternatively so that the manufacture of compost is continuous.

The Importance of Quality in Compost Making. Too much emphasis cannot be laid on the importance of quality in farm compost. The higher the quality, the better the crops and the finer the livestock.

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Small farms

The Earth's Green Carpet

By Louise E. Howard

Appendix B
List of Books

The list of books given here is far from exhaustive. The selection has been made from those likely to be most useful to the reader or which are authoritative in their special subjects.

1. Books on General Principles

Howard, A. and Wad, Y. D.: *The Waste Products of Agriculture: their Utilization as Humus.* 0.U.P., 1931, 167 pp.

Howard, Sir Albert: *An Agricultural Testament.* 0.U.P., 1941, 253 pp.

Howard, Sir Albert: *The Soil And Health.* The Devin-Adair Company, 1947, 307 pp.

Balfour, Lady Eve: *The Living Soil.* Faber & Faber, 1944, 248 pp.

Note. A list of the scientific papers published during their official career in India by Albert and Gabrielle Howard will be found in their book: The *Application of Science to Crop Production.* 0. U. P., 1929, pp. 62-7. This book describes the principles on which the Indore Institute of Plant Industry was founded.

2. Descriptive Books or Books Dealing with Practice

Sykes, Friend: *Humus and the Farmer.* Faber & Faber, 1946, 288 pp.

Rodale, J. I.: *Pay Dirt.* Devin-Adair Co., N.Y., 1945, 242 p

Drummond, John: *Inheritance of Dreams.* Faber & Faber: 1945, 219 pp.

King, F. C.: *The Compost Gardener*. Titus Wilson, Kendal, 1943.

Drummond, John: *Charter for the Soil*. Faber & Faber, 1944, 90 pp.

King, F. C.: *Gardening with Compost*. Faber & Faber, 1944, 116 pp.

Bromfield, Louis: *Pleasant Valley*. Cassell, 1946, 302 pp.

3. Books on Erosion

Sears, Paul B.: *Deserts on the March*. Univ. of Oklahoma Press, 1935, 231 pp.

Soils. and Men. U. S. A. Dept. of Agric. Yearbook for 1938, 1,232 pp.

Jacks, G. V. and Whyte, R. 0.: *The Rape of the Earth: a World Survey of Soil Erosion*. Faber & Faber, 1939, 313 pp.

Lilienthal, D. E.: *T. V. A. (Tennessee Valley Authority)*. A Penguin Special, 1944, 208 pp.

Lowdermilk, W. C.: *Palestine: Land of Promise*. Gollancz, 1944, 167 pp.

Bennett, H. H.: *Soil Erosion*. McGraw-Hill Publishing Co., 1946.

4. Books on Grassland Management

Elliot, R. H.: *The Clifton Park System of Farming*. Fifth edition. Faber & Faber, 1943, 261 pp. (First published under another title in 1898.)

Stapledon, Sir R. George: *The Hill Lands of Britain: Development or Decay*. Faber & Faber, 1937, 138 pp.

Stapledon, Sir R. George: *The Plough-Up Policy and Ley Farming*. Faber & Faber; and other works by the same author.

Graham, Michael: *Soil and Sense*. Faber & Faber, 1941, 274 pp.

5. Books on Humus, the Earthworm and the Mycorrhizal Association

Darwin, Charles: *Darwin on Humus and the Earthworm*. (A reprint of Darwin's original work.) With a Preface by Sir Albert Howard. Faber & Faber, 1945, 153 pp.

Waksman, Selman A.: *Humus, Origin, Chemical Composition and Importance in Nature*. Baillière, Tindal and Cox, 1936, 494 pp.

Rayner, M. C.: *Mycorrhiza.* C. U. P., 1927, 246 pp.

Rayner, M. C. and W. Neilson-Jones: *Problems in Tree Nutrition.* Faber & Faber, 1944, 181 pp.

Rayner, M. C.: *Trees and Toadstools.* Faber & Faber, 71 pp. (A popular account.)

6. Books on Chinese Agriculture

King, F. H.: *Farmers of Forty Centuries.* Jonathan Cape (first edition in England), 1926, 279 pp.

7. Books on Medical and Dental Aspects and Disease

Mcdonagh, J. E. R.: *The Universe Through Medicine.* Heinemann, 1940, 389 pp.

Picton, Lionel J.: *Thoughts on Feeding*, Faber & Faber, 1946, 265 pp.

Picton, Lionel J.: *Sun, Soil And Medicine*, The Devin-Adair Company, 1948

Price, Weston A.: *Nutrition and Physical Degeneration* (on dental problems). Published by the author at 1,020 Campus Avenue, Redlands, California, 1939, 527 pp.

Large, E. C.: *The Advance of the Fungi* (on the history of plant disease). Jonathan Cape, 1940, 488 pp.

8. Periodicals

The most important periodical being published at the moment on the problems discussed in this book is:

Soil and Health, edited by Sir Albert Howard. Four times yearly: subscription 5s. or $1.25 a year, to be sent to Miss Kirkham, The Rise, Milnthorpe, Westmorland. This carries on *The Compost News Letter,* edited by Dr. Lionel J. Picton, O. B. E., first issued in October 1941, under the authority of the Local Medical and Panel Committees of the County Palatine of Cheshire. In these two periodicals will be found a mass of information on every aspect of soil fertility drawn from current experience of those practicing the principles of organic farming.

Other periodicals are:

The Farmer: The Journal of Natural Farming and Living, edited by Mr. F. Newman Turner. Four times yearly; subscriptions 6s. 6d. a year, to be sent to *The Farmer*, Goose

Green Farm, Sutton Mallet, Bridgwater, Somerset. This is a journal especially for practical farmers, first appearing in the summer of 1946.

The Cross and the Plough: the organ of the Catholic Land Movement of England and Wales. Four times a year; subscription ls. a year, to be sent to Weeford Cottage, Hill, Sutton Coldfield.

Organic Gardening, edited by Mr. J. I. Rodale. Twelve times yearly; subscription $3.00 a year, to be sent to The Rodale Press, 6th and Minor Sts., Emmaus, Pa., U. S. A.

The Compost Magazine, of the Humic Compost Club, New Zealand. Six times yearly, subscription 6d. per number, or 5s. membership of the Club per annum, to Box 1303, Auckland, N. Z.

Veldt Trust News. Organ of the National Veldt Trust of the Union of South Africa. Subscription for membership of the Trust, Cl 1s. per year, to the National Veldt Trust, Box 31, Bloemfontein. This journal specializes on problems of erosion.

The Organic Farming Digest. Organ of the Organic Farming and Gardening Society, 50 Mitchell Street, North Bondi, New South Wales. Four times yearly; membership subscription, 5s. a year.

Mother Earth. Organ of the Soil Association, 8K Hyde Park Mansions, London, N. W. 1. Available to members of the Association only.

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