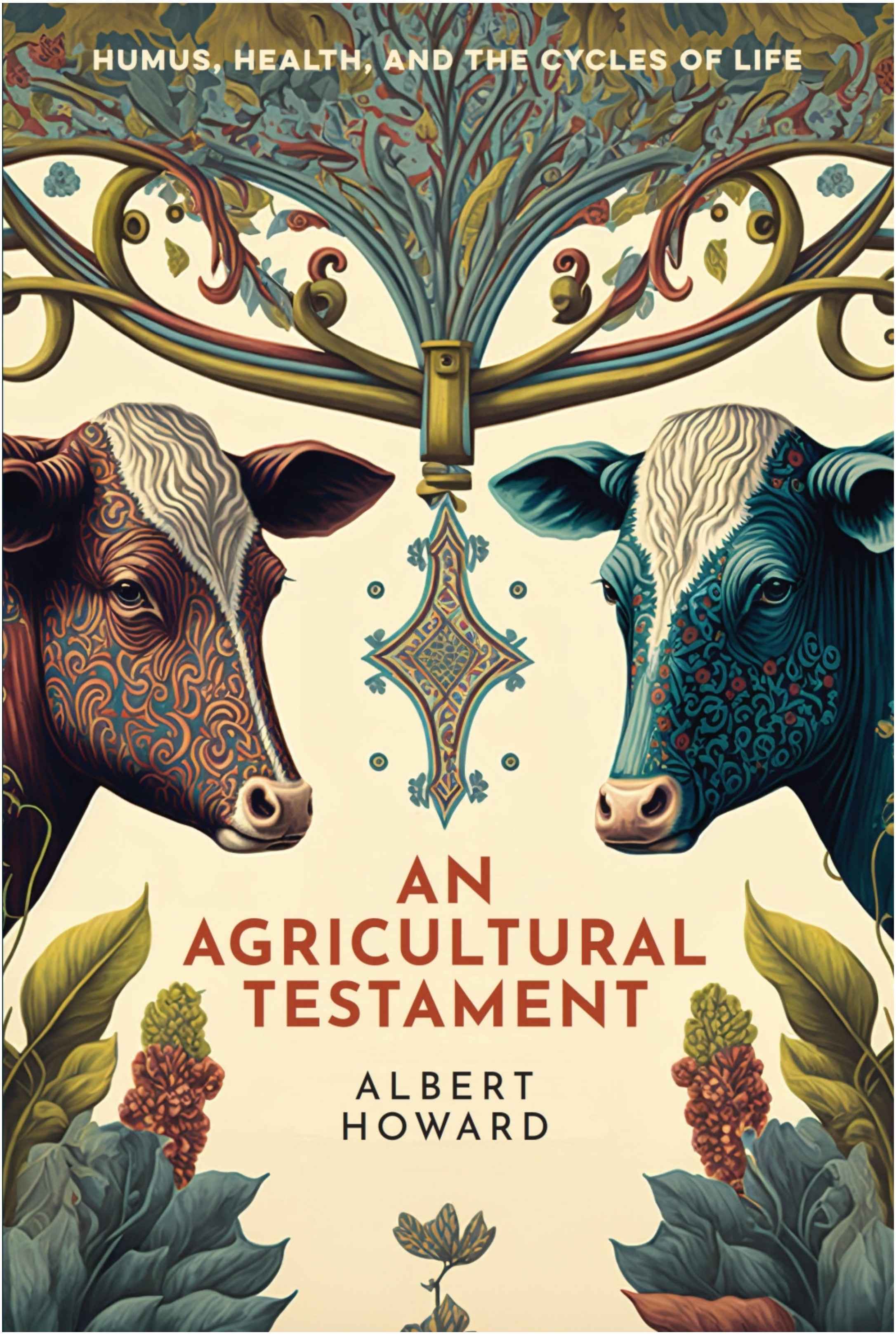
HUMUS, HEALTH, AND THE CYCLES OF LIFE
AN AGRICULTURAL TESTAMENT
ALBERT HOWARD

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ALBERT HOWARD

Hon. Fellow of the Imperial College of Science,
Former Director of the Indore Institute of Plant Industry,
and Agricultural Adviser to the States of India

A DISTANT MIRROR

AN AGRICULTURAL TESTAMENT

by Albert Howard

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Edited by David Major

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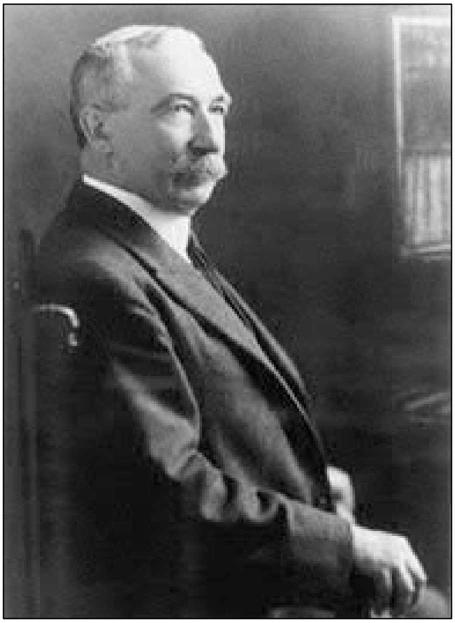

Sir Albert Howard (1873 – 1947) was an English botanist, and the first westerner to document and publish the Vedic Indian techniques of sustainable agriculture, now better known as organic farming. After spending years learning from both Indian peasants and the pests and diseases present in the soil, he called these two his 'professors'.

He was a principal figure in the early organic movement. He is considered by many to have been, along with Rudolf Steiner and Eve Balfour, one of the leading architects of the modern organic agriculture movement.

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Publisher's preface to the 2021 edition

Why is there a cow on the front cover of this book? This is a book about agriculture, and farm animals have become unfashionable in some quarters. Cows, it turns out, are responsible for global warming, climate change, and so, no doubt, rising sea levels and chemtrails.

But any real farmer, from any time in history, knows that this is not true. Animals have been around forever. Animals are a vital part of an insanely complex living system. Anyone who knows the basics of regenerative agriculture understands this.

Albert Howard spent years studying and using the methods of traditional Asian agriculture, and shows in this book that the fertility and health of the soil depend on humus, in the production of which animal materials play an vital role. A healthy soil needs animal inputs. Animals in agriculture are central; they're right in there with fungi.

This message is not welcomed by those who would feed the modern world a diet of plant-based, lab-grown food substitutes that have lists of ingredients as long as your arm, and are going to save the planet using gene-spliced soybeans and 3D printed pizzas.

So, the cow and her calf are on the cover to redress the balance, and also to feature as one of the stars of this book (along with sugar cane, waste pits, and public servants). She was the photogenic one.

Albert Howard's text has been thoroughly re-edited in this new version of his book. The habit, common at the time, of using long paragraphs is not preferred by modern readers, so the text has been extensively 'reparagraphed'. Grammar has been tweaked, and styles have been adopted. Headings have been added, infinitives unsplit.

The changes made have been to make things more comfortable for modern eyes and tastes. The sense and intention of the author has not been altered at all, of course. I hope that Albert Howard would approve of this reworking of his book. His ideas are more important than ever.

D. Major
April 2021

Publisher's preface to the 1972 edition

Since this book first appeared in 1940, it has been regarded as one of the most important contributions to the solution of soil rehabilitation problems ever published. More importantly, it has been regarded as the keystone of the organic movement.

The late Louis Bromfield called it "the best book I know of on soil and the processes which take part in it."

Soil Science called it "the most interesting and suggestive book on soil fertility which has appeared since King's *Farmers of Forty Centuries*.

Mother Earth News recently called it "the most basic of all introductions to organic farming, by the founder of the modern movement."

The object of the book was to draw attention to the loss of soil fertility, brought about by the vast increase in crop and animal production, that has led to such disastrous consequences as a general unbalancing of farming practices, an increase in plant and animal diseases and the loss of soil by erosion.

Howard contended that such losses can be repaired only by maintaining soil fertility by manufacturing humus from vegetable and animal wastes through the composting process. He stressed, too, a little-known nutritional factor – the mycorrhizal association, which is the living bridge of fungus that connects the humus in the soil and the sap of plants.

Howard's work is based up on the premise that good agricultural practice is based upon the observation and use of natural processes," wrote farmer-poet Wendell Berry in *The Last Whole Earth Catalog*.

"Howard's discoveries and methods, and their implications, are given in detail in *An Agricultural Testament*. They are of enormous usefulness to gardeners and farmers, and to anyone else who may be interested in the history and the problems of land use. But aside from its practical worth, Howard's book is valuable for his ability to place his facts and insights within the perspective of history. This book is a critique of civilisations, judging them not by their artefacts and victories but by their response to the sacred duty of handing over unimpaired to the next generation the heritage of a fertile soil."

It was a reading of this book which led the late J. Rodale to publish his first copy of *Organic Gardening and Farming,* the bible of the now widespread organic movement in America. Howard's work remains the keystone of that movement.

"In the reading of *An Agricultural Testament,* I was affected so profoundly that I could not rest until I purchased a farm," wrote Rodale. "The reading of this great book showed me how simple the practice of the organic method could be."

Author's preface to the 1940 edition

Since the Industrial Revolution, the processes of growth have been sped up to produce the food and raw materials needed by the population and the factory. Nothing effective has been done to replace the loss of fertility involved in this vast increase in crop and animal production.

The consequences have been disastrous. Agriculture has become unbalanced; the land is in revolt; diseases of all kinds are on the increase. And in many parts of the world, Nature is removing the worn-out soil by means of erosion.

The purpose of this book is to:

1. Draw attention to the destruction of the earth's soil.
2. Indicate some of the consequences of this.
3. Suggest methods by which the lost fertility can be restored.

This ambitious project is founded on the work and experience of 40 years, mainly devoted to agricultural research in the West Indies, India, and Great Britain. It is the continuation of an earlier book – *The Waste Products of Agriculture*, published in 1931 – in which the Indore method for maintaining soil fertility by the manufacture of humus from vegetable and animal wastes was described.

During the last nine years, the Indore Process has been taken up at many centres all over the world. Much additional information on the role of humus in agriculture has been obtained. I have also had the opportunity to review the existing systems of farming, as well as the organisation and purpose of agricultural research.

Attention has also been given to the biodynamic methods of agriculture in Holland and Great Britain – but I remain unconvinced that the disciples of Rudolph Steiner can offer any real explanation of natural laws, or have provided any practical examples which demonstrate the value of their theories.

The general results of all this are set out in this, my *Agricultural Testament*. No attempt has been made to disguise the conclusions reached or to express them in the language of diplomacy. On the contrary, they have been stated with the utmost frankness; it is hoped that they will be discussed with the same freedom, and that they will open up new lines of thought and eventually lead to effective action.

It would not have been possible to have written this book without the help and encouragement of a former colleague in India, George Clarke, who held the post of Director of Agriculture in the United Provinces for ten years (1921–31). He generously placed at my disposal his private notes on the agriculture of the Provinces covering a period of over twenty years, and has discussed with me during the last three years practically everything in this book. He read many of the chapters when they were first drafted, and made a number of suggestions which have been incorporated in the text.

Many who are engaged in practical agriculture all over the world, and who have adopted the Indore Process, have contributed to this book. In a few cases, mention of this assistance has been made in the text. It is impossible to refer to all the correspondents who have furnished progress reports and have so freely reported their results. These provided a valuable collection of facts and observations which has amply confirmed my own experience.

Great attention has been given to a hitherto undiscovered factor in nutrition – *the mycorrhizal association* – the living fungal bridge between humus in the soil and the sap of plants. The existence of such a symbiosis was first suggested to me on reading an account of remarkable results with conifers, obtained by Dr M. Rayner in connection with the operations of the Forestry Commission.

If mycorrhiza occurs generally in the plantation industries and also in our crops, an explanation of the development of quality, disease resistance, as well as the slow deterioration of the soil which follows the use of artificial manures, would be provided.

I accordingly collected a wide range of specimens likely to contain mycorrhiza, extending over the whole of tropical and temperate agriculture. I am indebted to Dr Rayner and to Dr Ida Levisohn for the detailed examination of this material. They have furnished me with many valuable technical reports. For the interpretation of these laboratory results, as set out in the following pages, I am solely responsible.

I am indebted to a number of societies for permission to reproduce information and illustrations which have already been published.

The Royal Society of London has permitted me to reprint, in the chapter on Soil Aeration, a *precis* of a paper from their *Proceedings*.

The Royal Sanitary Institute has agreed to the reproduction in full of a paper read at the Health Congress, held at Portsmouth in July 1938.

The British Medical Journal has placed at my disposal the information contained in an article by Dr Lionel Picton.

The publishers of Dr Waksman's monograph on humus have allowed me to reprint two long extracts relating to the properties of humus.

Guinness & Sons have agreed to the publication of the details of the composting of town wastes in their hop garden at Bodiam.

Messrs Walter Duncan & Co. have allowed the manager of the Gandrapara Tea Garden to contribute an illustrated article on the composting of wastes on this fine estate.

Captain J. Moubray has sent me an interesting summary of the work he is doing at Chipoli in Rhodesia, which is given in *Appendix 6.2*.

In making the Indore Process widely known, a number of journals have rendered great service. In Great Britain *The Times* and the *Journal of the Royal Society of Arts* have published a regular series of letters and articles. In South Africa the *Farmer's Weekly* has from the beginning urged the agricultural community to increase the humus content of the soil. In Latin America the planters owe much to the *Revista del Instituto de Defensa del éCaf de Costa Rica*.

Certain of the largest tea companies in London, James Finlay & Co., Walter Duncan & Co., the Ceylon Tea Plantations Company, Octavius Steel & Co., and others, most generously made themselves responsible over a period of two years for a large part of the office expenses connected with the working out and application to the plantation industries of the Indore Process. They also defrayed the expenses of a tour to the tea estates of India and Ceylon in 1937. These arrangements were very kindly made on my behalf by Mr G. Masefield, Chairman of the Ceylon Tea Plantations Company.

In the work of reducing to order the vast mass of correspondence and notes on soil fertility which have accumulated, and in getting the book into its final shape, I owe much to the ability and devotion of my private secretary, Mrs. V. Hamilton.

Albert Howard
1 January 1940

The Earth, that's Nature's Mother, is her tomb;
What is her burying grave, that is her womb.

Romeo and Juliet

And Nature, the old nurse, took
The child upon her knee,
Saying: 'Here is a story-book
Thy Father has written for thee.'

'Come, wander with me,' she said,
'Into regions yet untrod;
And read what is still unread
In the manuscripts of God.'

LONGFELLOW
The Fiftieth Birthday of Agassiz

Introduction

THE MAINTENANCE OF THE FERTILITY of the soil is the first condition of any permanent system of agriculture. In the ordinary processes of crop production, fertility is steadily lost; its continuous restoration through manuring and soil management is therefore imperative.

In the study of soil fertility, the first step is to review the various systems of agriculture which have evolved over time. These fall into four main groups:

1. The methods of Nature – the supreme farmer – as seen in the primeval forest, in the prairie, and in the ocean.
2. The agriculture of the nations of the past.
3. The practices of the East, which have been almost unaffected by Western science.
4. The methods in vogue in regions such as Europe and North America to which a large amount of scientific attention has been paid during the last hundred years.

1. Nature's methods of soil management

Little or no consideration is paid in the literature of agriculture to the means by which Nature manages land and conducts her water culture. Nevertheless, these natural methods of soil management must form the basis of all our studies of soil fertility.

What are the main principles underlying Nature's agriculture? These can most easily be seen in operation in our woods and forests.

Mixed farming is the rule. Plants are always found with animals: many species of plants and animals all live together. In the forest every form of animal life, from mammals to the simplest invertebrates, occurs. The vegetable kingdom exhibits a similar range: there is never any attempt at monoculture. Mixed crops and mixed farming are the rule.

The soil is always protected from the direct action of sun, rain, and wind. In this care of the soil, *strict economy* is the watchword: nothing is lost. The whole of the energy of sunlight is made use of by the foliage of both the forest canopy and the undergrowth. The leaves also break up the rainfall into fine spray so that it can more easily be dealt with by the litter of plant and animal remains which are the last line of defence of the precious soil. These methods of protection, so effective in dealing with sun and rain, also reduce the power of the strongest winds to a gentle air current.

The rainfall, in particular, is carefully conserved. A large portion is retained in the surface soil: the excess is gently transferred to the subsoil, and then in due course to the streams and rivers. The fine spray created by the foliage is transformed by the protective ground litter into thin films of water which move slowly downwards, first into the humus layer, and then into the soil and subsoil.

The soil and subsoil have been made porous in two ways: by the creation of a well-marked crumb structure, and also by a network of drainage and aeration channels made by earthworms and other burrowing animals.

The pore space of the forest soil is at its maximum so that there is a large internal soil surface over which the thin films of water can creep. There is also ample humus for the direct absorption of moisture. The excess drains away slowly by way of the subsoil.

There is remarkably little run-off, even from the primeval rain forest. When this occurs, it is practically clear water. Hardly any soil is removed. Nothing in the nature of soil erosion occurs. The streams and rivers in forest areas are always perennial because of the vast quantity of water in slow transit between the rainstorms and the sea. There is, therefore, little or no drought in forest areas, because so much of the rainfall is retained exactly where it is needed. There is no waste anywhere.

The forest manures itself. It makes its own humus and supplies itself with minerals. If we watch a piece of woodland, we find that a gentle accumulation of mixed vegetable and animal residues is constantly taking place on the ground, and that these wastes are being converted by fungi and bacteria into humus.

The processes involved in the early stages of this transformation depend throughout on oxidation; afterwards they take place in the absence of air. They are sanitary. There is no nuisance of any kind – no smell, no flies, no dustbins, no incinerators, no artificial sewage system, no water-borne diseases, no town councils, and no rates.

On the contrary, the forest provides a location for the ideal summer holiday: sufficient shade and an abundance of pure fresh air. Nevertheless, all over the surface of the woods the conversion of vegetable and animal wastes into humus is never so rapid and so intense as during the holiday months – July to September.

The mineral matter needed by the trees and the undergrowth is obtained from the subsoil. This is collected in dilute solution in water by the deeper roots, which also help in anchoring the trees. The details of root distribution and the manner in which the subsoil is thoroughly combed for minerals are referred to in a later chapter.

Even in soils markedly deficient in phosphorus, trees have no difficulty in obtaining ample supplies of this element. Potash, phosphate, and other minerals are always collected *in situ* and carried by the transpiration current for use in the green leaves. Afterwards, they are either used in growth or deposited on the floor of the forest in the form of vegetable waste – one of the constituents needed in the synthesis of humus. This humus is again utilised by the roots of the trees.

Nature's farming, as seen in the forest, is characterised by

1. Constant circulation of the minerals absorbed by the trees.
2. Constant addition of new mineral matter from the vast reserves held in the subsoil.

There is, therefore, no need to add phosphates: there is no necessity for more potash salts. No mineral deficiencies of any kind occur. The supply of all the manure needed is automatic, and is provided either by humus or by the soil. There is a natural division of the subject into organic and inorganic. Humus provides the organic manure, while the soil provides the mineral matter.

The soil always carries a large fertility reserve. There is no hand-to-mouth existence involved in Nature's farming. The reserves are held in the upper layers of the soil in the form of humus. Yet any useless accumulation of humus is prevented because it is automatically mingled with the upper soil by the activities of burrowing animals such as earthworms and insects.

The extent of this enormous reserve is only realised when the trees are cut down and the virgin land is used for agriculture. When crops such as tea, coffee, rubber, and bananas are grown on recently cleared land, good yields can be raised without manure for ten years or more. Like all good administrators, therefore, Nature carries strong liquid reserves that are effectively invested. There is no squandering of these reserves to be seen anywhere.

The crops and livestock look after themselves. Nature has never found it necessary to design the equivalent of the spraying machine or chemical poison for the control of insect and fungal pests. There is nothing in the nature of vaccines and serums for the protection of the livestock. It is true that all kinds of diseases are to be found here and there among the plants and animals of the forest, but these never assume large proportions. The principle followed is that the plants and animals can protect themselves, even when such things as parasites are to be found in their midst. Nature's rule in these matters is to live and let live.

If we study the prairie and the ocean, we find that similar principles are followed. The grass carpet deals with the rainfall very much as the forest does. There is little or no soil erosion: the run-off is practically clear water. Humus is again stored in the upper soil.

The best of the grassland areas of North America carried a mixed herbage which maintained vast herds of bison. No veterinary service was needed to keep these animals alive. When brought into cultivation by the early settlers, so great was the store of fertility that these prairie soils yielded heavy crops of wheat for many years without livestock and without manure. That is a measure of how important animals can be in maintaining the health of the soil.

In lakes, rivers, and the sea, mixed farming is again the rule. A great variety of plants and animals are found living together, and nowhere does one find monoculture. The vegetable and animal wastes are again dealt with by effective methods. Nothing is wasted. Humus again plays an important part and is found everywhere in solution, in suspension, and in the deposits of mud. The sea, like the forest and the prairie, manures itself.

The main characteristics of Nature's farming are these:

1. Mother Earth never farms without livestock.
2. She always raises mixed crops.
3. Great pains are taken to preserve the soil, and to prevent erosion.
4. The mixed vegetable and animal wastes are converted into humus.
5. There is no waste.
6. The processes of growth and the processes of decay balance one another.
7. Ample provision is made to maintain large reserves of fertility.
8. The greatest care is taken to store the rainfall.
9. Both plants and animals are left to protect themselves against disease.

In considering the various man-made systems of agriculture which so far have been devised, it will be interesting to see how far Nature's principles have been adopted, whether they have ever been improved upon, and what happens when they are disregarded.

2. The agriculture of the nations of the past

The difficulties inherent in the study of the agriculture of cultures which no longer exist are obvious.

Unlike their buildings, where it is possible from a critical study of the buried remains of cities to reproduce a picture of bygone civilisations, the fields and farms of the ancients have seldom been maintained. The land has either gone back to forest, or has been used for one system of farming after another.

In one case, however, the actual fields of a bygone people have been preserved together with the irrigation methods by which their lands were made productive. No written records, alas, have come down to us of the staircase cultivation of the ancient Peruvians, perhaps one of the oldest forms of Stone Age agriculture.

This system of agriculture arose either in mountains or in the upland areas under grass because of the difficulty, before the discovery of iron, of removing the dense forest growth. In Peru, irrigated staircase farming seems to have reached its highest known development.

More than twenty years ago, the National Geographical Society of the United States sent an expedition to study the relics of this ancient method of agriculture, an account of which was published in the Society's magazine of May 1916, under the title *Staircase Farms of the Ancients*.

The system of the megalithic people of old Peru was to construct a stairway of terraced fields up the slopes of the mountains, tier upon tier, sometimes as many as 50 in number. The outer retaining walls of these terraces were made of large stones which fit into one another with such accuracy that even today, like those of the Egyptian pyramids, a knife blade cannot be inserted between them. After the retaining wall was built, the foundation of the future field was prepared by means of coarse stones covered with clay. On this base layers of soil, several feet thick, originally imported from beyond the great mountains, were superimposed and then levelled for irrigation. The final result was a small flat field with only just sufficient slope for artificial watering.

In other words, a series of huge flower pots, each provided with ample drainage below, was prepared with incredible labour by this ancient people for their crops. Such were the megalithic achievements in agriculture, beside which

> … our undertakings sink into insignificance before what this vanished race accomplished. The narrow floors and steep walls of rocky valleys that would appear utterly worthless and hopeless to our engineers were transformed, literally made over, into fertile lands and were the homes of teeming populations in prehistoric days.[1]

The engineers of old Peru did what they did through necessity, because iron, steel, reinforced concrete, and modern sources of power had not been invented. The plunder of the forest soil was beyond their reach.

These terraced fields had to be irrigated. Water had to be supplied to them over immense distances by means of aqueducts. Prescott states that one which traversed the district of Condesuyu measured between four and five hundred miles. Cook gives a photograph of one of these channels as a thin dark line traversing a steep mountain wall many hundreds of feet above the valley.

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1. Cook, O. *NGS Magazine*, May 1916, 'Staircase Farms of the Ancients'

These ancient methods of agriculture are represented today by the terraced cultivation of the Himalayas, of the mountainous areas of China and Japan, and of the irrigated rice fields so common in the hills of South India, Ceylon, and the Malayan archipelago.

Conway's description, published in 1894, of the terraces of the Hunza on the North-West Frontier of India, and of the canal, which stretched for long distances across the face of precipices to the one available supply of water – the torrent from the Ultor glacier – tallies almost completely with what he found in 1901 in the Bolivian Andes. This distinguished scholar and mountaineer considered that the native population of Hunza of today is living in a stage of civilisation that must bear some likeness to that of the Peruvian Inca. An example of this ancient method of farming has thus been preserved through the ages.

In *Chapter 3.4*, the relation which exists between the nutritional value of the food grown on these irrigated terraces and the health of the people will be discussed. This relic of the past is interesting from the point of view of quality in food, as well as for its historical value.

Some other systems of agriculture of the past have come down to us in the form of written records which have furnished ample material for constructive research. In the case of Rome in particular, a fairly complete account of the position of agriculture, from the period of the monarchy to the fall of the Roman Empire, is available; the facts can be conveniently followed in the writings of Mommsen, Heitland, and other scholars.

Rome's Servian Reform (Servius Tullius, 578–534 B.C.) shows clearly not only that the agricultural class originally dominated the State, but also that an effort was made to maintain the collective body of freeholders as the pith and marrow of the community. The conception that the constitution itself rested on the freehold system permeated the Roman attitude to war and conquest. The aim of war was to increase the number of its freehold members.

> The vanquished community was either compelled to merge into the yeomanry of Rome, or, if not reduced to this extremity, it was required not to pay a fixed tribute, but to cede a portion, usually a third part, of its domain, which was then regularly turned into Roman farms.
>
> Many nations have gained victories and conquests as the Romans did; but none has equalled the Roman in thus

> making the ground he had won his own by the sweat of his brow, and in securing by the ploughshare what had been gained by the lance. That which is gained by war may be wrested from the grasp by war again, but it is not so with the conquests made by the plough. The Romans lost many battles, but they scarcely ever on making peace ceded Roman soil, and this was due to the tenacity with which the farmers clung to their fields and homesteads.
>
> The strength of man and the State lies in their dominion over the soil; the strength of Rome was built on the mastery of her citizens over the soil, and on the unity of the body of citizens which thus acquired so firm a hold.[2]

These splendid ideals did not persist. During the period which elapsed between the union of Italy and the subjugation of Carthage, a gradual decay of the farmers set in. Small-holdings ceased to yield any substantial clear return; the cultivators faced ruin; the moral tone and frugal habits of the earlier ages of the Republic were lost, and the lands of the Italian farmers became merged into the larger estates.

The landlord capitalist became the central character. He not only produced at a cheaper rate than the farmer because he had more land, but he began to use slaves. The same space which had previously, when small-holdings prevailed, supported from 100 to 150 families was now occupied by one family of free persons and about 50, for the most part unmarried, slaves.

> If this was the remedy by which the decaying national economy was to be restored to vigour, it bore, unhappily, an aspect of extreme resemblance to disease.[3]

The main causes of this decline were fourfold:

1. The constant drain on the manhood of the countryside by the legions, which culminated in the two long wars with Carthage.
2. The operations of the Roman capitalist landlords, which contributed quite as much as Hamilcar and Hannibal to the decline in the vigour and the number of the Italian people.
3. Failure to work out a balanced agriculture between crops and livestock, and so maintain the fertility of the soil.
4. The employment of slaves instead of free labourers.

2,3. Mommsen, T. *The History of Rome*, London, 1894.

During this period, the wholesale commerce of Latium passed into the hands of the large landed proprietors who at the same time were the speculators and capitalists. The natural consequence of this was the destruction of the middle classes, particularly of the small-holders, and the development of landed and moneyed lords on the one hand and an agricultural proletariat on the other.

The power of capital was greatly enhanced by the growth of a class of tax-farmers and contractors, to whom the State farmed out the collection and management of its indirect revenues for a fixed sum.

Subsequent political and social conflicts did not give real relief to the agricultural community. Colonies founded to secure Roman sovereignty over Italy provided farms for the agricultural proletariat, but the root causes of the decline in agriculture were not removed, in spite of the efforts of Cato and other reformers. A capitalist system, of which the apparent interests were fundamentally opposed to a sound agriculture, remained supreme.

The last half of the second century saw degradation, and increasing decadence. Then came Tiberius Gracchus and the Agrarian Law, with the appointment of an official commission to counteract the diminution of the farmer class by the comprehensive establishment of new small-holdings from the property that was at the disposal of the State. 80,000 new Italian farmers were provided with land.

These efforts to restore agriculture to its rightful place in the State were accompanied by many improvements in Roman agriculture which, unfortunately, were most suitable for large estates. Land no longer able to produce corn became pasture; cattle now roamed over large ranches; the vine and the olive were cultivated with commercial success. These systems of agriculture, however, had to be carried on with slave labour, the supply of which had to be maintained by the constant addition of fresh slaves.

Such extensive methods of farming naturally failed to supply sufficient food for the population of Italy. Other countries were called upon to furnish essential food; province after province was conquered in order to feed the growing proletariat with corn. These areas in turn slowly yielded to the same decline which had taken place in Italy.

Finally, the wealthy classes abandoned the depopulated remnants of the mother country and built themselves a new capital at Constantinople. The situation had to be saved by a migration to fresh lands. In their new capital, the Romans relied on the unexhausted fertility of Egypt as well as on that of Asia Minor and the Balkan and Danubian provinces.

The agricultural history of the Roman Empire ended in failure due to its inability to realise the fundamental principle that the maintenance of soil fertility coupled with the legitimate claims of the agricultural population should never have been allowed to come into conflict with the operations of the capitalist.

The most important possession of a country is its population. If this is maintained in health and vigour, then everything else will follow; if this is allowed to decline nothing, not even great riches, can save the country from eventual ruin.

It follows, therefore, that the strongest possible support of capital must always be a prosperous and contented countryside. A working compromise between agriculture and finance should therefore have been evolved; failure to achieve this naturally ended in the ruin of both.

3. The practices of the East

In the agriculture of Asia, we find ourselves confronted with a system of peasant farming which, in its essentials, was stable. What is happening today in the small fields of India and China also took place many centuries ago.

There is here no need to study historical records, or to pay a visit to the remains of the megalithic farming of the Andes. The agricultural practices of the East have passed the supreme test – they are almost as permanent as those of the primeval forest, of the prairie or of the ocean. The smallholdings of China, for example, are still maintaining a steady output, and there is no loss of fertility after 40 centuries of management.

What are the chief characteristics of this Eastern farming?

Firstly, the holdings are tiny. Taking India as an example, the relation between manpower and cultivated area is referred to in the *Census Report* of 1931:

> For every agriculturalist, there are 2.9 acres of cropped land, of which 0.65 of an acre is irrigated. The corresponding figures of 1921 are 2.7 and 0.61.

These figures show how intense is the struggle for existence in this part of the tropics. These small holdings are often cultivated by extensive methods (those suitable for large areas) which utilise neither the full energies of man or beast, nor the potential fertility of the soil.

If we turn to the far East, to China and Japan, a similar system of small holdings is accompanied by an even more intense pressure of population, both human and bovine.

In the introduction to *Farmers of Forty Centuries*, King states that the three main islands of Japan had in 1907 a population of 46,977,000, maintained on 20,000 square miles of cultivated fields. This is at the rate of 2,349 to the square mile, or more than three people to each acre. In addition, Japan fed on each square mile of cultivation a very large animal population; 69 horses and 56 cattle, nearly all employed in labour, 825 poultry, 13 swine, plus goats and sheep.

Although no accurate statistics are available in China, the examples quoted by King reveal a condition of affairs not unlike that in Japan. In Shantung Province, a farmer with a family of twelve kept one donkey, one cow, and two pigs on 2.5 acres of cultivated land – a density of population at the rate of 3,072 people, 256 donkeys, 256 cattle, and 512 pigs per square mile. The average of seven Chinese holdings visited gave a maintenance capacity of 1,783 people, 212 cattle or donkeys, and 399 pigs – nearly 2,000 consumers and 400 food transformers per square mile of farmed land.

In comparison with these remarkable figures, the corresponding statistics for 1900 in the case of the United States per square mile were: population 61, horses and mules 30.

Food and forage crops are predominant. The primary function of Eastern agriculture is to supply the cultivators and their cattle with food. This automatically follows because of the pressure of the population on the land: the main hunger the soil has to appease is that of man and his animals.

Another hunger is that of machines, which constantly need raw materials for manufacture. This hunger is new, but has developed considerably since the opening of the Suez Canal in 1869 (by which the small fields of the cultivator have been brought into effective contact with the markets of the West) and the establishment of local industries such as cotton and jute.

To both these hungers, soil fertility must respond. We know from long experience that the fields of India can respond to the hunger of the stomach; whether they can fulfil the added demands of the machines remains to be seen.

The Suez Canal has only been in operation for 70 years. The first cotton mill in India was opened in 1818 at Fort Gloster, near Calcutta. The jute industry of Bengal has grown up within a century. Jute was first exported in 1838. The first jute mill began operations in 1855. These local industries as well as the export trade in raw products for the use of the factories of the West are an extra drain on soil fertility.

Their future wellbeing and indeed their very existence is only possible provided adequate steps are taken to maintain this fertility. There is obviously no point in establishing cotton and jute mills in India, in founding trading agencies such as those of Calcutta, and in building ships for the conveyance of raw products unless such enterprises are stable and permanent. It would be folly, and an obvious waste of capital, to pursue such activities if they were to be founded only on the existing store of soil fertility.

All concerned in the administration of machinery – government, financiers, manufacturers, and distributors – must see to it that the fields of India are equal to the new burden which has been thrust upon her during the last 50 years or so. The demands of commerce and industry on the one hand, and the fertility of the soil on the other, must be maintained in correct relation the one to the other.

The response of India to the two hungers – the stomach, and the machine – will be evident from a study of *Table 1* on the opposite page, in which the area in acres under food and fodder crops is compared with that under money crops.

The chief food crops, in order of importance, are rice, pulses, millets, wheat, and fodder crops. The money crops are more varied; cotton and oil seeds are the most important, followed by jute and other fibres, tobacco, tea, coffee, and opium. It will be seen that food and fodder crops comprise 86% of the total area under crops and that money crops, as far as extent is concerned, are less important, and constitute only one-seventh of the total cultivated area.

One interesting change in the production of Indian food crops has taken place during the last 25 years. The output of sugar had previously been insufficient for the towns, and large quantities were imported from Java, Mauritius, and the continent of Europe. Today, thanks to the

Acres under food and fodder crops	
Rice	79,888,000
Millets	38,144,000
Wheat	25,150,000
Gram	14,897,000
Pulses and other food grains	29,792,000
Fodder crops	10,791,000
Condiments, spices, fruits, vegetables and misc. crops	8,308,000
Barley	6,178,000
Maize	6,211,000
Sugar	4,038,000
Total food and fodder crops	223,397,000
Acres under money crops	
Cotton	15,761,000
Oil seeds, chiefly ground-nuts, sesamum, rape, mustard and linseed	15,662,000
Jute and other fibres	2,706,000
Dyes, tanning materials, drugs, narcotics, and miscellaneous	1,458,000
Tobacco	1,230,000
Tea	787,000
Coffee	97,000
Indigo	40,000
Opium	10,000
Total money crops	37,751,000

Table 1. Agricultural statistics of British India, 1935-6

work at Shahjahanpur in the United Provinces, the new varieties of cane bred at Coimbatore, and the protection now enjoyed by the sugar industry, India is almost self-supporting as far as sugar is concerned. Before the First World War, the average amount of sugar imported was 634,000 tons; by 1937–8, the total had fallen to 14,000 tons.

Mixed crops are the rule. In this respect, the farmers of the Orient have followed Nature's method as it exists in the primeval forest. Mixed cropping is perhaps most universal when the cereal crop is the main constituent. Crops such as millet, wheat, barley, and maize are mixed with an appropriate subsidiary pulse, sometimes a species that ripens much later than the cereal. The pigeon pea (*Cajanus cajan*), perhaps the most important leguminous crop of the Gangetic alluvium, is often grown either with millet or maize.

The mixing of cereals and pulses appears to help both crops. When the two grow together, the character of their growth improves. Do the roots of these crops excrete materials useful to each other? Is the mycorrhizal association found in the roots of these tropical legumes and cereals the agent involved in this excretion?

Science is currently unable to answer these questions: it is only now beginning to investigate them. Here we have another instance in which the peasants of the East have anticipated and acted upon the solution of one of the problems which Western science is only just beginning to recognise. Whatever may be the reason that crops thrive best when associated in suitable combinations, the fact remains that mixtures generally give better results than monoculture.

This is seen in Great Britain in the growth of dredge corn, in mixed crops of wheat and beans, vetches and rye, clover and rye-grass, and in intensive vegetable growing under glass. The produce raised under Dutch lights has noticeably increased since the mixed cropping of the Chinese vegetable growers of Australia has been copied. Mr F. Secrett was, I believe, the first to introduce this system on a large scale into Great Britain. He informed me that he saw it for the first time in Melbourne.

A balance between livestock and crops is always maintained. Although crops are generally more important than animals in Eastern agriculture, we seldom, if ever, find crops without animals. This is because oxen are required for cultivation and buffaloes for milk. The buffalo is the milk cow of the East, and is capable not only of useful labour in the cultivation of rice, but also of producing large quantities of rich milk on a diet on which the best dairy cows of Europe and America would starve. The acclimatisation of the Indian buffalo in the villages of the Tropics – Africa, Central America, the West Indies in particular – would do much to improve the fertility of the soil and the nutrition of the people.

Nevertheless, the waste products of the animal, as is often the case in other parts of the world, are not always fully utilised for the land.

The Chinese have for ages past recognised the importance of the urine of animals and the great value of animal wastes in the preparation of composts. In India, far less attention is paid to these wastes, and a large portion of the cattle dung available is burnt for fuel.

On the other hand, in most countries in the East, human wastes find their way back to the land. In China, these are collected for manuring the crops directly. In India they are concentrated on the zone of highly manured land immediately around each village. If the population, or a portion of it, could be persuaded to use a more distant zone for a few years, the area of village lands under intensive agriculture could at least be doubled.

Here is an opportunity for the new system of government in India to raise production without the expenditure of a single rupee. In India, there are 500,000 villages, each of which is surrounded by a zone of fertile land which is constantly being over-manured by human waste.

If we examine the crops grown on this land, we find that the yields are high, and the plants are remarkably free from disease. But although half a million examples of the connection between a fertile soil and healthy plants exist in India alone – and these natural experiments have been in operation for centuries before experimental stations such as Rothamsted were ever thought of – modern agricultural science takes no notice of the results, and resolutely refuses to accept them as evidence, largely because they lack the support of modern mathematics and statistics.

The Indian experience also debunks one of the ideas of the disciples of Rudolph Steiner, who argue that the use of human waste in agriculture is harmful.

Leguminous plants are common. Although it was not until 1888, after a controversy lasting 30 years, that Western science finally accepted the important part played by pulse crops in enriching the soil, centuries of experience had taught the peasants of the East the same lesson. The leguminous crop as part of the rotation is everywhere one of their old fixed practices. In some areas, such as the Indo-Gangetic plain, one of these pulses – the pigeon pea – is also made use of as a subsoil cultivator. The deep spreading root system is used to promote the aeration of the closely packed silt soils, which so closely resemble those of the Holland Division of Lincolnshire in Great Britain.

Cultivation is generally superficial and is carried out by wooden ploughs furnished with an iron point. Soil-inverting ploughs, as used in the West for the destruction of weeds, have never been adopted by Eastern peoples. The reasons for this appear to be two:

1. Soil inversion for the destruction of weeds is not necessary in a hot climate, where the same work is done by the sun for nothing.
2. The preservation of the level of the fields is essential for surface drainage, for preventing local waterlogging, and for irrigation.

Another reason for this surface cultivation has recently been pointed out. The store of nitrogen in the soil in the form of organic matter has to be carefully conserved; it is part of the farmer's working capital. Too much cultivation and deep ploughing would oxidise this reserve, and the balance of soil fertility would soon be destroyed.

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Rice is grown whenever possible. It is by far the most important crop in the East. In India, as has already been pointed out, the production of rice exceeds that of any two other food crops put together. Whenever the soil and water supply permit, rice is invariably grown.

A study of this crop is illuminating. At first sight rice appears to contradict one of the great principles of the agricultural science of the West – namely, the dependence of cereals on nitrogenous manures. Large crops of rice are produced in many parts of India on the same land year after year, without the addition of any manure whatever. The farms of the countryside export rice in large quantities to the centres of population or abroad, but there is no corresponding import of combined nitrogen.

Taking Burma as an example of a country exporting rice internationally; during the 20 years ending 1924, about 25 million tons of rice have been exported from a tract roughly ten million acres in area. As unhusked rice contains about 1.2% of nitrogen the amount of this element, shipped overseas during 20 years or destroyed in the burning of the husk, is in the neighbourhood of 300,000 tons.

As this constant drain of nitrogen is not compensated for with the addition of manure, we should expect to find a gradual loss of fertility. Nevertheless, this does not take place either in Burma or Bengal, where rice has been grown on the same land, year after year, for centuries.

Clearly the soil must obtain fresh supplies of nitrogen from somewhere, otherwise the crop would cease to grow.

Where does the rice crop obtain its nitrogen? One source in all probability is fixation from the atmosphere in the submerged algal film on the surface of the mud.

Another is the rice nursery itself, where the seedlings are raised on land heavily manured with cattle dung. Large quantities of nitrogen and other nutrients are stored in the seedling itself; this at transplanting time contains a veritable arsenal of reserves of all kinds which carry the plant successfully through this process and probably also furnish some of the nitrogen needed during subsequent growth.

The manuring of the rice seedling illustrates a general principle in agriculture: the importance of starting a crop in a really fertile soil, and so arranging matters that the plant can absorb a great deal of what it needs as early as possible in its development.

There is an adequate supply of labour. Labour is everywhere abundant, as would naturally follow from the great density of the rural population. Indeed, in India it is so great that if the leisure time of the farmers and their cattle for a single year could be calculated as money, a colossal figure would be obtained.

This leisure, however, is not altogether wasted. It enables the farmers and their oxen to recover from the periods of intensive work which precede the sowing of the crops and which are needed again at harvest time. At these periods, time is everything: everybody works from sunrise to sunset. The preparation of the land and the sowing of the crops need the greatest care and skill; the work must be completed in a short time, which means that a large labour force is essential.

It will be observed that in this peasant agriculture, the great pressure of population on the soil results in poverty, most marked where, as in India, extensive methods are used on small-holdings which really need intensive farming. It is amazing that in spite of this unfavourable factor, soil fertility should have been preserved for centuries: this is because natural means have been used, and not artificial fertilisers. The crops are able to withstand the inroads of insects and fungi without the use of 'protective' poisons.

4. The agricultural methods of the West

If we make a survey of the contribution which is being made by the fields and farms of the West, we find that they are engaged in trying to satisfy no less than three hungers.

1. The local hunger of the rural population, including the livestock.
2. The hunger of the growing urban areas, the population of which is unproductive from the point of view of soil fertility.
3. The hunger of the machine for a constant stream of the raw materials required for manufacture. The urban population has grown incredibly during the last century; the needs of the machine increase as it becomes more efficient; falling profits are met by increasing the output of manufactured articles.

All this adds to the burden on the land and to the demands on its fertility. It will be interesting to analyse critically the agriculture of the West, and see how it is fitting itself out for its growing task.

This can be done by examining its main characteristics.

1. *The holding tends to increase in size.* There is a great variation in the size of the agricultural holdings of the West, from the small family units of France and Switzerland to the immense collective farms of Russia, and the spacious ranches of the United States and Argentina.
2. *The lessening of the number of workers per square mile.*
   In Canada, for example, the number of workers per 1,000 acres of cropped land fell from 26 in 1911, to 16 in 1926. Since these data were published, the size of the working population has shrunk still further. This state of things has arisen from the scarcity and cost of labour, which has naturally led to the development of labour-saving devices.
3. *Monoculture is the rule.* Almost everywhere, crops are grown as monoculture. Except in temporary leys, mixed crops are rare. On the rich prairie lands of North America even rotations are unknown; crops of wheat follow one another and no attempt is made to convert the straw into humus. The straw is seen as a tiresome encumbrance, and is burnt off annually.

4. *The machine is rapidly replacing the animal.* Increasing mechanisation is one of the main features of Western agriculture. Whenever a machine can be invented which saves human or animal labour, its spread is rapid. Engines and motors of various kinds are the rule everywhere. The electrification of agriculture is a fact. The inevitable march of the combine harvester in all the wheat-producing areas of the world is one of the latest examples of the mechanisation of the agriculture of the West.
5. *Cultivation tends to be quicker and deeper.* There is a growing feeling that the more and the deeper the soil is stirred, the better will be the crop. The invention of the gyrotiller, a heavy and expensive soil churn, is one of the answers to this demand.
6. *The human slaves of the Roman Empire have been replaced by mechanical slaves.* The replacement of the horse, the ox, and the Roman slave by the internal combustion engine and the electric motor is, however, attended by one great disadvantage. These machines do not produce urine and dung, and so contribute nothing to the maintenance of soil fertility. In this sense, the new slaves of Western agriculture are less efficient than those of ancient Rome.
7. *Artificial fertilisers are widely used.* The defining feature of the manuring of the West is the use of artificial fertilisers. The factories engaged during the Great War in the fixation of atmospheric nitrogen for the manufacture of explosives had to find other markets, and so the use of nitrogenous fertilisers in agriculture increased, until today the majority of farmers and market gardeners base their manure programme on the cheapest forms of nitrogen (N), phosphorus (P), and potassium (K) that they can get. What may be described as the 'NPK mentality' dominates farming in both the experimental stations and the countryside. Vested interests, entrenched during a time of national emergency, have gained a stranglehold.

8. *Artificial fertilisers involve less labour and less trouble than farmyard manure.* The tractor is superior to the horse in power and in speed of work: it needs no food and no expensive care during its long hours of rest. These two facts have made it easier to run a farm. A satisfactory profit-and-loss account has been obtained. For the moment farming has been made to pay. But there is another side to this picture.

9. *These chemicals and these machines do nothing to keep the soil in good heart.* With their use, the processes of growth can never be in balance with the processes of decay. All that they can accomplish is the transfer of the soil's capital to the 'current account'. This will be obvious to the world when the attempts now being made to farm without any animals proceed to their inevitable failure.

10. *Diseases are on the increase.* With the spread of artificials and the exhaustion of the original supplies of humus that are carried by every fertile soil, there has been a corresponding increase in the diseases of both crops and the animals which feed on them.

    If the spread of foot-and-mouth disease in Europe and its comparative insignificance among well fed animals in the East are compared, or if the comparison is made between certain areas in Europe, the conclusion is inevitable: there must be an intimate connection between faulty methods of agriculture and animal disease. In crops such as potatoes and fruit, the use of poison spray has closely followed the reduction in the supplies of farmyard manure, and the diminution of fertility.

11. *Food preservation processes* are making great advances. A feature of the agriculture of the West is the development of food preservation, by which the time spent transporting products such as meat, milk, vegetables, and fruit to the consumer can be prolonged. This is done by freezing, by the use of carbon dioxide, by drying, and by canning. Although food is preserved for a time in this way, what is the effect of these processes on the health of the community during a period of, say, 25 years? Is it possible to preserve the initial freshness of food? If so, then science will have made a very real contribution.

12. Another of the features of the agriculture of the West is *the development of agricultural science.* Great efforts have been made to enlist the help of a number of sciences in studying the problems of agriculture and in increasing the production of the soil. This has entailed the foundation of many experimental stations, which every year pour out a large volume of advice in the form of printed matter.

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These approaches to agriculture are failing; the Earth, deprived of her 'manurial rights' is in revolt. The land is going on strike, and the fertility of the soil is declining.

An examination of the areas which feed the population and the machines of a country such as Great Britain leaves no doubt that the soil is no longer able to stand the strain.

Soil fertility is rapidly diminishing, particularly in the United States, Canada, Africa, Australia, and New Zealand. In Great Britain itself, real farming has already been given up, except on the best lands. The loss of fertility all over the world is indicated by the growing menace of soil erosion.

The seriousness of the situation is proved by the attention now being paid to this matter by the world's press and governments. In the United States, for example, the whole resources of government are being mobilised to save what is left of the good earth.

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The agricultural record has been briefly reviewed from the standpoint of soil fertility. The main characteristics of the various methods of agriculture have been summarised.

The most significant of these are the operations of Nature as seen in the forest. There the fullest use is made of sunlight and rainfall in raising heavy crops of produce, and at the same time not only maintaining fertility but actually building up large reserves of humus.

The peasants of China, who pay great attention to the return of all wastes to the land, come nearest to the ideal set by Nature. They have maintained a large population on the land, without any falling off in fertility.

The agriculture of ancient Rome failed because it was unable to maintain the soil in a fertile condition; and the farmers of the West are repeating the mistakes made by Imperial Rome.

The soils of the Roman Empire, however, were only called upon to assuage the hunger of a relatively small population. The demands of the machine were then almost non-existent. In the modern world, there are relatively more stomachs to fill, while the growing hunger of the machine is an additional burden on the soil.

The Roman Empire lasted for 11 centuries. How long will the West endure? The answer depends on the wisdom and courage of the population in dealing with the things that matter.

Can mankind regulate its affairs so that its chief possession – the fertility of the soil – is preserved?

The future of civilisation depends on the answer to this question.

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1

SOIL FERTILITY AND AGRICULTURE

1.1 The Nature of Soil Fertility

What is soil fertility?

What, exactly, does it mean?

How does it affect the soil, the crop, and the animal?

How can we best investigate it?

An attempt will be made in this chapter to answer these questions, and to show why soil fertility must be the basis of any permanent system of agriculture.

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The nature of soil fertility can only be understood if it is considered in relation to Nature's cycles. In this study, we must at the outset free ourselves from the conventional approach to agricultural problems by means of the separate sciences – and, above all, we must resist consideration of statistical evidence derived from field experiments.

Instead of dismembering agriculture into fragments, and studying the subject in piecemeal fashion with the methodologies of analytical science – appropriate only to the discovery of new facts – we must instead adopt a synthetic approach, and consider the wheel of life as one great subject, and not as a patchwork of unrelated things.

All the phases of the cycles of life are closely connected; all are integral to Nature's activity. All are equally important, and none can be omitted. We must therefore study soil fertility in relation to a natural working system, and adopt methods of investigation in strict relation to such a subject. We need not strive after quantitative results: the qualitative will serve.

We must look at soil fertility as we would study a business where the profit and loss account must be considered along with the balance sheet, the standing of the concern, and the method of management. It is the 'altogetherness' which matters in business, not some particular transaction or the profit or loss of the current year. So it is with soil fertility. We have to consider the wood, not the individual trees.

The wheel of life is made up of two processes – growth and decay. The one is the counterpart of the other.

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Let us first consider growth. The soil yields crops. These form the food of animals. Crops and animals are taken into the human body, and are digested there.

The perfectly grown, normal, vigorous human being is the highest natural development known to us. There is no break in the chain from soil to man; this section of the wheel of life is uninterrupted throughout. It is also an integration; each step depends on the last. It must therefore be studied as a working whole.

The energy for the machinery of growth is derived from the sun. The chlorophyll in the green leaf is the mechanism by which this energy is intercepted; the plant is thereby enabled to manufacture food – to synthesise carbohydrates and proteins from the water and other substances taken up by the roots and the carbon dioxide of the atmosphere.

The efficiency of the green leaf is therefore of supreme importance; on it depends the food supply of this planet, our well-being, and our activities. There is no alternative source of nutriment. Without sunlight and the green leaf, our industries, our trade, and our possessions would soon be useless.

The chief factors on which the work of the green leaf depends are the condition of the soil, and its relation to the roots of the plant. The plant and the soil come into gear by means of the root system in two ways – by the root hairs, and by the mycorrhizal association.

The first condition for this gearing is that the internal surface of the soil – the pore space – should be as large as possible throughout the life of the crop. It is on the walls of this pore space, which are covered with thin water films, that the essential activities of the soil take place. The soil population, which consists mainly of bacteria, fungi and protozoa, carry on their life processes in these water films.

The root hairs

The contact between the soil and the plant which is best understood takes place by means of the root hairs. These are elongations of the outer layer of cells of the young root. Their duty is to absorb from the thin films of moisture on the walls of the pore space all the water and dissolved salts required for the work of the green leaves. No actual food can reach the plant in this way; only the simple elements which are needed by the green leaf to synthesise food.

The activities of the pore space depend on respiration, for which adequate quantities of oxygen are essential. A corresponding amount of carbon dioxide is the natural by-product. To maintain the oxygen supply and reduce the amount of carbon dioxide, the pore spaces must be kept in contact with the atmosphere; in other words, the soil must be ventilated – hence the importance of cultivation.

As most of the soil organisms possess no chlorophyll, and, moreover, have to work in the dark, they must somehow be supplied with energy.

This is obtained by the oxidation of humus – the name given to a complex residue of partly oxidised vegetable and animal matter, together with the substances synthesised by the fungi and bacteria which break down these wastes.

This humus also helps to provide the cement which enables the minute mineral soil particles to aggregate into larger compound particles, and so maintain the pore space.

If the soil is deficient in humus, the following sequence occurs:

- The volume of the pore space is reduced.
- The aeration of the soil is impeded.
- There is insufficient organic matter for the soil population.
- The machinery of the soil runs down.
- The supply of oxygen, water, and dissolved salts needed by the root hairs is reduced.
- The synthesis of carbohydrates and proteins in the green leaf proceeds at a lower tempo.
- Growth is affected.

Humus is therefore an essential material for the soil if the first phase of the life cycle is to function.

There is another reason why humus is important. Its presence in the soil is an essential condition for the proper functioning of the second contact between soil and plant – the mycorrhizal relationship.

The mycorrhizal relationship

By means of this connection, certain soil fungi, which live on humus, are able to invade the living cells of the young roots and establish an intimate relation with the plant, the details of which symbiosis are still being investigated and discussed. Soil fungus and plant cells therefore live together in closer partnership than the algal and fungal constituents of the lichen do.

How the fungus benefits has yet to be determined. How the plant profits is easier to understand. If a suitable preparation of such roots is examined under the microscope, all stages in the digestion of the fungal mycelium can be seen. At the end of the partnership the root consumes the fungus, and in this manner is able to absorb the carbohydrates and proteins which the fungus obtains partly from the humus in the soil.

The mycorrhizal association therefore is the living bridge by which a fertile soil (one rich in humus) and the crop are directly connected, and by which food materials ready for immediate use can be transferred from soil to plant.

How this association influences the work of the green leaf is one of the most interesting problems science has now to investigate.

Is the effective synthesis of carbohydrates and proteins in the green leaf dependent on the digestion products of these soil fungi? It is probable that this will prove to be the case.

Are these digestion products at the root of disease resistance and quality? It would appear so. If this is the case, it would follow that on the efficiency of this mycorrhizal association, the health and well-being of mankind must depend.

In a fertile soil, the soil and the plant come into gear in two ways simultaneously. In establishing and maintaining these contacts, humus is essential. It is therefore a key material in the life cycle. Without this substance, the wheel of life cannot function effectively.

The processes of decay which complete the wheel of life can be seen in operation on the floor of any woodland. This has already been discussed. It has been shown how the mixed animal and vegetable wastes are converted into humus and how the forest manures itself.

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Such are the essential facts in the wheel of life. Growth on the one side, and decay on the other.

In Nature's farming, a balance is struck and maintained between these two complementary processes. The only man-made systems of agriculture – those found in the East – which have stood the test of time have faithfully copied this rule from Nature.

It follows, therefore, that the correct relation between the processes of growth and decay is the first principle of successful farming. Agriculture must always be balanced. If we speed up growth, we must accelerate decay.

If, on the other hand, the soil's reserves are squandered, crop production ceases to be good farming: it becomes something quite different. The farmer has literally become a bandit.

It is now possible to define more clearly the meaning of 'soil fertility'.

It is the condition of a soil rich in humus, in which the growth processes proceed rapidly, smoothly, and efficiently. The term therefore connotes such things as abundance, high quality, and resistance to disease. A soil which grows to perfection a grain crop can be described as fertile. A pasture on which meat and milk of the first class are produced falls into the same category. An area under market-garden crops on which vegetables of the highest quality are raised has reached the peak as regards fertility.

Why does soil fertility so markedly influence the soil, the plant, and the animal? By virtue of the humus it contains. The nature and properties of this substance as well as the products of its decomposition are therefore important. These matters will now be considered.

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What is humus? This question has been answered by the appearance in 1938 of the second edition of Waksman's admirable text on humus, in which the results of no less than 1,311 original papers have been put in order and collated. Waksman defines humus as:

> … a complex aggregate of brown to dark-coloured amorphous substances which have originated during the decomposition of plant and animal residues by micro-organisms, under aerobic and anaerobic conditions, usually in soils, composts, peat bogs, and water basins.
>
> Chemically, humus consists of various constituents of the original plant material resistant to further decomposition; of

> substances undergoing decomposition; of complexes resulting from decomposition either by processes of hydrolysis or by oxidation and reduction; and of various compounds synthesised by micro-organisms.
>
> Humus is a natural body; it is a composite entity, just as are plant, animal, and microbial substances; it is even more complex chemically, since all these materials contribute to its formation.
>
> Humus possesses certain specific physical, chemical, and biological properties which make it distinct from other natural organic bodies.
>
> Humus, in itself or by interaction with certain inorganic constituents of the soil, forms a complex colloidal system, the different constituents of which are held together by surface forces; this system is adaptable to changing conditions of reaction, moisture, and action by electrolytes. The numerous activities of the soil micro-organisms take place in this system to a large extent.

Viewed from the standpoint of chemistry and physics, humus is therefore not a simple substance: it is made up from a group of complex organic compounds depending on the nature of the residues from which it is formed, on the conditions under which decomposition takes place, and on the extent to which the processes of decay have proceeded.

Humus, therefore, cannot be exactly the same thing everywhere. It is bound to be a creature of circumstance.

Moreover, it is alive, and teems with a vast range of micro-organisms which derive most of their nutriment from this substratum. Humus in the natural state is dynamic, not static.

From the point of view of agriculture, therefore, we are dealing not with simple dead matter such as a sack of sulphate of ammonia, which can be analysed and valued according to its chemical composition, but with a vast organic complex, in which an important section of the farmer's invisible labour force – the organisms which carry on the work of the soil – is temporarily housed. Humus, therefore, involves the element of labour; in this respect also it is one of the most important factors on the farm.

It is essential at this point to pay some attention to the many-sided properties of humus, and to realise how profoundly it differs from any artificial fertiliser. At the moment, all over the world, field trials – based on mere nitrogen content – are in progress, comparing, on various crops, dressings of humus and various artificial compounds.

A mere glance at the properties of humus will show that such field trials are based on a fundamental misunderstanding of what soil fertility implies, and are misleading – and therefore useless.

The properties of humus have been summed up by Waksman:

1. Humus possesses a dark brown to black colour.
2. Humus is practically insoluble in water, although a part of it may go into colloidal solution in pure water. Humus dissolves to a large extent in dilute alkaline solutions, especially on boiling, giving a dark coloured extract; a large part of this extract precipitates when the alkaline solution is neutralised by mineral acids.
3. Humus contains a somewhat larger amount of carbon than do plant, animal, and microbial bodies; the carbon content of humus is usually about 55 to 56%, and frequently reaches 58%.
4. Humus contains considerable nitrogen, usually about 3–6%. The nitrogen concentration may be frequently less than this figure; in the case of certain high-moor peats, for example, it may be only 0.5 to 0.8%. It may also be higher, especially in subsoils, frequently reaching 10–12%.
5. Humus contains the elements carbon and nitrogen in proportions which are close to 10:1; this is true of many soils and of humus in sea bottoms. This ratio varies considerably with the nature of the humus, the stage of its decomposition, the nature and depth of soil from which it is obtained, and the climatic and other conditions under which it is formed.
6. Humus is not in a static, but rather in a dynamic, condition, since it is constantly formed from plant and animal residues, and is continually being decomposed further by micro-organisms.
7. Humus serves as a source of energy for the development of various groups of micro-organisms, and during decomposition gives off a continuous stream of carbon dioxide and ammonia.
8. Humus is characterised by a high capacity of base exchange, of combining with various other soil constituents, of absorbing water, and of swelling, and by other physical and chemical properties which make it a highly valuable constituent of substrates which support plant and animal life.

Finally, to this list of properties must be added the role of humus as a cement in creating and maintaining the compound soil particles so important to the maintenance of tilth.

The effect of humus on the crop is nothing short of profound; farmers and peasants who live in close touch with Nature can tell with a single glance at the crop whether or not the soil is rich in humus.

The habit of the plant then develops something approaching personality; the foliage assumes a characteristic set; the leaves acquire the glow of health; the flowers develop depth of colour; the minute morphological characters of all the plant's organs become clearer and sharper. Root development is profuse: the active roots exhibit not only turgidity, but bloom.

The influence of humus on the plant is not confined to the outward appearance of the various organs; the quality of the produce is also affected. Seeds are better developed, and so yield better crops and also provide livestock with a satisfaction not conferred by the produce of worn-out land. The animals need less food if it comes from fertile soil. Vegetables and fruit grown on land rich in humus are always superior in quality, taste, and keeping power to those raised by other means. The quality of wines, other things being equal, follows the same rule. Almost every villager in countries such as France appreciates these points, and will talk of them freely without the slightest prompting.

In the case of fodder, an interesting example of the relation between soil fertility and quality has recently been investigated. This was noticed in the meadows of La Crau, between Salon and Aries in Provence. Here the fields are irrigated with muddy water, containing finely divided limestone drawn from the Durance, and manured mostly with farmyard manure. The soils are open and permeable, the land is well drained naturally. All the factors on which soil fertility depends are present together – an open soil with ample organic matter, adequate moisture, and the ideal climate for growth.

Any farmer who saw these meadows for the first time would at once be impressed by them. A walk through the fields during hay-making would confirm for him the fact that it pays the owners of high-quality animals to obtain their roughage from this distant source. Several cuts of hay are produced every year, which enjoy such a reputation for quality that the bales are sent long distances by truck to the various racing stables of France, and are even exported to Newmarket. The small stomach of the racehorse needs the very best food possible, and this the meadows of La Crau produce.

The origin of these irrigated meadows would provide an interesting story. Did they arise as the result of a set of permanent experiments with fertilisers on the Broadbalk model – or through the work of some observant local pioneer?

I suspect the second alternative will be found to be nearer the truth. A definite answer to this question is desirable because in a recent discussion at Rothamsted, on the relation between a fertile soil and high-quality produce, it was stated tha*t no evidence of such a connection could be discovered in the literature.*

The farmers of Provence, however, have supplied it and also a measure of quality in the shape of a satisfactory price. For the present the only way of measuring quality seems to be by selling it. It cannot be weighed and measured by the methods of the laboratory. Nevertheless it exists; moreover, it constitutes an important factor in agriculture.

Apparently some of the experimental stations have not yet come to grips with this factor; but the farmers have. The sooner, therefore, that effective liaison is established between these two agencies, the better.

The effect of soil fertility on livestock can be observed in the field. As animals live on crops, we should naturally expect the character of the plant as regards nutrition to be passed on to stock; and this is so. The effect of a fertile soil can at once be seen in the condition of the animals.

This is perhaps most easily observed in the bullocks fattened on some of the notable pastures in Great Britain. The animals show a well-developed bloom, the coat and skin look and feel right, and the eyes are clear, bright, and lively. The posture of the animal confirms health and well-being.

It is not necessary to weigh or measure them. A glance on the part of a successful farmer, or of a butcher accustomed to dealing with high class animals, is sufficient to tell them whether all is well, or whether there is something wrong with the soil or the management of the animals, or both. The results of a fertile soil and proper methods of management are measured by the prices these animals fetch in the market and the standing of the farmer in these markets.

It should be a compulsory item in the training of agricultural investigators for them to accompany some of the best of our English cattle from the pasture to the market, and watch what happens there.

They would find that the most fertile pastures produce the best animals, that auctioneers and buyers detect quality instantly, and that such animals find a ready sale, and command the best prices.

Resistance to insect and fungal disease is also conferred by humus. Perhaps the best examples of this are to be seen in the East. In India, the crops grown on the highly fertile soils around the 500,000 villages there suffer remarkably little from pests. This subject is developed at length in *Chapter 3.3*, when the retreat of both crops and animals before parasites is discussed.

Soil fertility not only influences crops and livestock but also the fauna of the locality. This is perhaps most easily seen in the fish of streams which flow through areas of widely differing degrees of fertility. An example of such difference is referred to in Isaak Walton's *Compleat Angler*:

> And so I shall proceed next to tell you, it is certain, that certain fields near Leominster, a town in Herefordshire, are observed to make sheep that graze upon them more fat than the next, and also to bear finer wool; that is to say, that in that year in which they feed in such a particular pasture, they shall yield finer wool than they did that year before they came to feed in it, and coarser again if they shall return to their former pasture; and again return to a finer wool, being fed in the fine wool ground.
>
> Which I tell you, that you may the better believe that I am certain, if I catch a trout in one meadow he shall be white and faint, and very likely to be lousy; and as certainly if I catch a trout in the next meadow, he shall be strong and red and lusty and much better meat: trust me, scholar. I have caught many a trout in a particular meadow, that the very shape and enamelled colour of him hath been such as hath joyed me to look on him: and I have then with much pleasure concluded with Solomon that "everything is beautiful in its season".

Soil fertility is the condition which results from the operation of Nature's round, from the orderly revolution of the wheel of life, from the adoption and faithful execution of the first principle of agriculture: *that there must always be a perfect balance between the processes of growth and the processes of decay*.

The consequences of this condition are a living soil, abundant crops of good quality, and livestock which possess the bloom of health.

And the key to a fertile soil and a prosperous agriculture is humus.

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1.2 *The Restoration of Fertility*

The moment mankind undertook the business of raising crops and breeding animals, the processes of Nature were subjected to interference. Soil fertility was exploited for the growing of food and the production of the raw materials – wool, skins, and vegetable fibres – needed for clothing.

Up to the dawn of the Industrial Revolution in the West, the losses of humus involved in these operations were made up either by the return of waste material to the soil, or by taking over fresh virgin land.

Where the return of wastes balanced the losses of humus involved in production, systems of agriculture became stabilised, and there was no loss of fertility. The example of China has already been quoted. The old mixed farming of a large part of Europe, including Great Britain – characterised by a correct balance between arable land and livestock, the conversion of wastes into farmyard manure, methods of sheep folding, and the use of the temporary ley – is another example.

The constant exploitation of new areas to replace worn-out land has gone on for centuries, and is still taking place. Sometimes this has involved wars and conquests; at other times, it has meant nothing more than taking up fresh prairie or forest land wherever this was to be found.

A special method is adopted by some tribes. The forest growth is burnt down, the store of humus is converted into crops, and then the exhausted land is given back to Nature for reafforestation and the building up of a new reserve of humus. In this rough and ready way, fertility is maintained. Such shifting cultivation still exists all over the world, but like the taking up of new land, is possible only when the population is small, and suitable land abundant.

This burning process has even been incorporated into permanent systems of agriculture and has proved of great value in rice cultivation in western India. Here the intractable soils of the rice nurseries have to be prepared during the last part of the hot season so that the seedlings are ready for transplanting by the break of the monsoon. This is achieved by covering the nurseries with branches collected from the forest, and setting fire to the mass. The heat destroys the colloids, restores the tilth, and makes the manuring and cultivation of the rice nurseries possible.

It is an easy matter to destroy a balanced agriculture. Once the demand for food and raw materials increases and good prices are obtained for the produce of the soil, the pressure on soil fertility becomes intense. The temptation to convert this fertility into money becomes irresistible.

Western agriculture was subjected to this strain by the rapid developments which followed the invention of the steam engine, the internal combustion engine, electrically driven motors, and improvements in communications and transport. Factory after factory appeared; a demand for labour followed; the urban population increased.

All these developments provided new and expanding markets for food and raw materials. These were supplied in three ways – by cashing in the existing fertility of the whole world, by the use of a temporary substitute for soil fertility in the form of artificial fertilisers, and by a combination of both methods. The net result has been that agriculture has become unbalanced, and therefore unstable.

Let us review briefly the operations of Western agriculture from the point of view of the utilisation of wastes, in order to discover whether the gap between the losses and gains of humus, now bridged by artificials, can be reduced or abolished altogether. If this is possible, something can be done to restore the balance of agriculture and to make it more stable, and therefore more permanent.

Many sources of organic soil matter exist:

1. The roots of crops, weeds, and crop residues which are turned under in the course of cultivation.
2. The algae met with in the surface soil.
3. Temporary leys, the turf of worn-out grass land, catch crops, and green-manures.
4. The urine of animals.
5. Farmyard manure.
6. The contents of the dustbins of our cities and towns.
7. Factory wastes from the processing of agricultural produce.
8. The wastes of the urban population.
9. Water-weeds, including seaweed.

These must now be briefly considered. In later chapters, most of these matters will be referred to again and discussed in greater detail.

The residues turned under in the course of cultivation

It is not always realised that about half of every crop – the root system – remains in the ground at harvest time, and thus provides a continuous return of organic matter to the soil. The weeds and their roots that are ploughed in during the ordinary course of cultivation add to this supply.

When these residues, supplemented by the fixation of nitrogen from the atmosphere, are accompanied by skillful soil management, which safeguards the precious store of humus, crop production can be maintained at a low level without the addition of any manure whatsoever beyond the occasional droppings of livestock and birds.

A good example of such a system of farming without manure is to be found in the alluvial soils of the United Provinces in India where the field records of ten centuries prove that the land produces small crops year after year without any falling off in fertility. A perfect balance has been reached between the nutritional requirements of the crops harvested and the natural processes which recuperate fertility.

The greatest care, however, is taken not to over-cultivate, not to cultivate at the wrong time, or to stimulate the soil processes by chemical manures.

Systems of farming such as these supply the base-line for agricultural development. A similar though not so convincing result is provided by the permanent wheat plot at Rothamsted, where this crop has been grown on the same land without manure since 1844. This plot, which has been without manure of any kind since 1839, showed a slow decline in production for the first 18 years, after which the yield has been practically constant. The reserves of humus in this case left over from the days of mixed farming evidently lasted for nearly 20 years.

There are, however, two obvious weaknesses in this experiment. This plot does not represent any system of agriculture, it only speaks for itself. Nothing has been done to prevent earthworms and other animals from bringing in a constant supply of manure, in the shape of their wastes, from the surrounding land. It is much too small to yield a significant result.

Soil algae

Soil algae are a much more important factor in the tropics than in temperate regions. Nevertheless, they occur in all soils and often play a part in the maintenance of soil fertility.

Towards the end of the rainy season in countries such as India, a thick algal film occurs on the surface of the soil which immobilises a large amount of combined nitrogen otherwise likely to be lost by leaching. While this film is forming, cultivation is suspended and weeds are allowed to grow.

Just before the sowing of the cold weather crops in October, the land is thoroughly cultivated, during which this easily decomposable and finely divided organic matter, which is rich in nitrogen, is transformed into humus and then into nitrates.

How far a similar method can be utilised in colder countries is a matter for investigation. In the East, cultivation always fits in with the life-cycle in a remarkable way. In the West cultivation is regarded as an end in itself and not, as it should be, as a factor in the wheel of life. Europe has much to learn from Asia in the cultivation of the soil.

Temporary leys, catch-crops, green-manures, and the turf of worn-out grass land

These are perhaps the most important source of humus in Western agriculture. All these crops develop a large root system; the permanent and temporary leys give rise to ample residues of organic matter which accumulate in the surface soil. Green-manures and catch-crops develop a certain amount of soft and easily decomposable tissue. Provided these crops are properly utilised, a large addition of new humus can be added to the soil. The efficiency of these methods of maintaining soil fertility could, however, be very greatly increased.

The urine of animals

The key substance in the manufacture of humus from vegetable wastes is urine – the drainage of the active cells and glands of the animal. It contains in a soluble and balanced form all the nitrogen and minerals, and in all probability the accessory growth-substances as well, needed for the work of the fungi and bacteria which break down the various forms of cellulose – the first step in the synthesis of humus. It carries in all probability every raw material, known and unknown, discovered and undiscovered, needed in the building up of a fertile soil. Much of this vital substance for restoring soil fertility is either wasted or only imperfectly utilised. This fact alone would explain the disintegration of the agriculture of the West.

Farmyard manure

Although farmyard manure has always been one of the principal means of replenishing soil losses, even now the methods by which this substance is prepared are nothing short of deplorable. The making of farmyard manure is the weakest link in the agriculture of Western countries. For centuries this weakness has been the fundamental fault of Western farming, one completely overlooked by many observers and the great majority of investigators.

Dustbin refuse

Practically no agricultural use is now being made of the impure cellulose and kitchen wastes which find their way into the urban dustbin. These are mostly buried in controlled tips or burnt.

Animal residues

A number of wastes connected with the processing of food and some of the raw materials needed in industry are utilised on the land and find a ready market. The animal residues include such materials as dried blood, feathers, greaves, hair waste, hoof and horn, rabbit waste, slaughter-house refuse, and fish waste.

There is a brisk demand for most of these substances, as they give good results on the land. The drawback is the limited supplies available.

The organic residues from manufacture consist of damaged oil-cakes, shoddy and tannery waste, of which shoddy, a by-product of the wool industry, is the most important. These two classes of wastes, animal and industrial, are applied to the soil direct and, generally speaking, command much higher prices than would be expected from their content of nitrogen, phosphorus, and potash.

It is probable that a better use for these wastes will be found as raw materials for the compost heaps of the future, where they will act as substitutes for urine in the breaking down of dustbin refuse in localities where the supply of farmyard manure is restricted.

Water weeds

Little use is made of water weeds in maintaining soil fertility. Perhaps the most useful of these is seaweed, which is thrown up on the beaches in large quantities at certain times of the year and which contains iodine and includes the animal residues needed for converting vegetable wastes into humus. Many of our seaside resorts could easily manufacture from seaweed and dustbin refuse the vast quantities of humus needed for the farms and market gardens in their neighbourhood and so balance the local agriculture.

Little or nothing, however, is being done in this direction. In some cases the seaweed on beaches is taken up by the farmers with good results, but the systematic utilisation of seaweed in the compost heap is still a matter for the future.

The streams and rivers which carry off the surplus rainfall also contain appreciable quantities of combined nitrogen and minerals in solution. Much of this could be intercepted by the cultivation of suitable plants on the borders of these streams which would furnish large quantities of material for humus manufacture.

Human night soil and urine

Human excrement is at present almost completely lost to the land. In urban areas, the concentration of the population is the main reason why water-borne sewage systems have developed. The greatest difficulty in the path of the reformer is the absence of sufficient land for dealing with these wastes. In country districts, however, there are no insurmountable obstacles to the utilisation of human wastes.

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It is evident that in almost every case the vegetable and animal residues of Western agriculture are either being completely wasted, or else imperfectly utilised. A wide gap between the humus used up in crop production and the humus added as manure has naturally developed. This need has been met by artificial fertilisers. The principle followed, based on the Liebig tradition, is that any deficiencies in the soil solution can be made up by the addition of suitable chemicals.

This is based on a complete misconception of plant nutrition. It is superficial and fundamentally unsound. It takes no account of the life of the soil, including the mycorrhizal association – the living fungal bridge which connects soil and sap. Artificial fertilisers lead inevitably to artificial nutrition, artificial food, artificial animals, and finally to artificial men and women.

The ease with which crops can be grown with chemicals has made the correct utilisation of wastes much more difficult.

If a cheap substitute for humus exists, why not use it?

The answer is twofold.

1. Chemicals can never be a substitute for humus because Nature insists that the soil must live, and that the mycorrhizal association is an essential link in plant nutrition.

2. The use of such a substitute cannot be cheap because soil fertility – one of the most important assets of any country – is lost; because artificial plants, artificial animals, and artificial men are unhealthy and can only be protected from the parasites, whose duty it is to remove them, by means of poison sprays, vaccines and serums and an expensive system of patent medicines, panel doctors, hospitals, and so forth.

   When the finance of crop production is considered together with that of the various social services which are needed to repair the consequences of an unsound agriculture, and when it is borne in mind that our greatest possession is a healthy, virile population, the cheapness of chemical fertilisers disappears altogether.

In the years to come, chemical fertilisers will be regarded as one of the great follies of the industrial epoch. The teachings of the agricultural economists of this period will be dismissed as superficial nonsense.

In the next section we will discuss the methods by which the agriculture of the West can be reformed and balanced, and the use of artificial fertilisers given up.

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2

THE INDORE PROCESS

2.1 *The Indore Process*

The Indore Process for the manufacture of humus from vegetable and animal wastes was devised at the Institute of Plant Industry, Indore, Central India, between the years 1924 and 1931. It was named after the Indian State in which it originated, in grateful remembrance of all that the Indore Darbar did to make my task in Central India easier and more pleasant.

Although the working out of the actual process only took seven years, the foundations on which it is based occupied me for more than a quarter of a century. Two independent lines of thought and study led up to the final result.

One of these concerns the nature of disease, and is discussed more fully in *Chapter 3.3*. It was observed in the course of these studies that the maintenance of soil fertility is the real basis of health and resistance to disease. The various parasites were found to be only secondary matters: their activities resulted from the breakdown of a complex biological system – the soil in its relation to the plant and to the animal. This was due to improper methods of agriculture, an impoverished soil, or to a combination of both.

The second line of thought arose in the course of 19 years (1905–24) spent in plant-breeding at Pusa, when it was gradually realised that the full possibilities of the improvement of the variety can be achieved only when the soil in which the new types are grown is provided with an adequate supply of humus.

Improved varieties by themselves could be relied upon to give an increased yield in the neighbourhood of 10%. Improved varieties plus better soil conditions were found to produce an increment up to 100%, or even more.

As an addition of even 10% to the yield would ultimately impose a severe strain on the frail fertility reserves of the soils of India and would gradually lead to their impoverishment, plant-breeding, to achieve any permanent success, would have to include a continuous addition to the humus content of the small fields of the Indian cultivators. The real problem was not the improvement of the variety, but how to make the variety and the soil both more efficient.

By about the year 1918, these two hitherto independent approaches to the problems of crop production – by way of pathology, and by way of plant-breeding – began to coalesce. It became clearer and clearer that agricultural research itself was involved in the problem; that the organisation was responsible for the failure to recognise the things that matter in agriculture and would therefore have to be reformed. The separation of work on crops into such compartments as plant-breeding, mycology, entomology, and so forth, would have to be given up; the plant would have to be studied in relation to the soil on the one hand, and to the agricultural practices of the locality on the other.

An approach to the problems of crop production on such a wide front was impossible in a research institute such as Pusa, in which the work on crops was divided into no less than six separate sections. The working out of a method of manufacturing humus from waste products and a study of the reaction of the crop to improved soil conditions would encroach on the work of practically every section of the Institute.

As no progress has ever been made in science without complete freedom, the only way of studying soil fertility as one subject appeared to be to found a new institute, in which the plant would be the centre of the subject, and where science and practice could be brought to bear on the problem without any concern about the existing organisation of agricultural research.

Thanks to the support of a group of Central Indian States and a large grant from the Indian Central Cotton Committee, the Institute of Plant Industry was founded at Indore in 1924. Central India was selected as the home of this new research centre for two reasons:

1. The offer of a 99 year lease of an area of 300 acres of suitable land by the Indore Darbar.
2. The absence in the Central India Agency of any organised system of agricultural research. This tract therefore provided both the land and the freedom from interference required for research based on the humus content of the soil, and the problems underlying crop production. An account of the organisation of the Institute of Plant Industry was published as *The Application of Science to Crop Production* (OUP, 1929).

The work at Indore accomplished two things:

1. The obsolete character of the present-day organisation of agricultural research was demonstrated.
2. A practical method of manufacturing humus was devised.

The Indore Process was first described in detail in 1931, in *Chapter 4* of *The Waste Products of Agriculture*. Since then, the method has been taken up by most of the plantation industries and also on many farms and gardens around the world. In the course of this work, nothing has been added to the two main principles underlying the process:

1. The combination of vegetable and animal wastes, with a base for neutralising acidity.
2. The management of the mass so that the micro-organisms which do the work can function in the most effective manner.

A number of minor changes in working have, however, been suggested. Some of these have proved advantageous in increasing the output. In the following account the original description has been followed, but all useful improvements have been incorporated so that the technique has been brought up to date.

The raw materials needed

Vegetable wastes

In temperate countries such as Great Britain, these include: straw, chaff, damaged hay and clover, hedge and bank trimmings, weeds including seaweed and water weeds, prunings, hop-vine and hop-string, potato haulm, market-garden residues including those of the greenhouse, bracken, fallen leaves, sawdust, and wood shavings. A limited amount of other vegetable material, such as the husks of cotton seed, cacao, ground nuts, and banana stalks, are also available near some of the large cities.

In the tropics and sub-tropics, the vegetable wastes consist of similar materials, including the vegetation of waste areas, grass, plants grown for shade and green-manure, sugar cane leaves and stumps, all crop residues not consumed by livestock, cotton stalks, weeds, sawdust and wood shavings, and plants grown for providing compostable material on the borders of fields and roadsides.

A continuous supply of mixed dry vegetable wastes throughout the year, in a proper state of division, is the chief factor in the process. The ideal chemical composition of these materials should be such that, after being used as bedding for livestock, the carbon-to-nitrogen ratio is in the region of 33:1.

The material should also be in such a physical condition that the fungi and bacteria can obtain ready access to and break down the tissues without delay. The bark, which is the natural protection of the celluloses and lignins against the inroads of fungi, must first be destroyed. This is the reason why all woody materials – such as cotton and pigeon-pea stalks – were always laid on the roads at Indore and broken down by traffic prior to composting.

Worldwide, one of the first objections to the adoption of the Indore Process is that there is nothing worth composting, or only small supplies of such material. In practically all such cases, any shortage of wastes has been remediated through effective use of the land and by growing plants for composting on every possible square foot of soil.

If Nature's way of using sunlight to the full in the virgin forest is compared to that on the average farm or on the average tea and rubber estate, it will be seen what leeway can be made up by growing suitable material for making humus.

Sometimes the objection is heard that all this will cost too much. The answer is found in the dust bowls of North America. The soil must have its manurial rights, or farming dies.

Animal residues

The animal residues ordinarily available all over the world are much the same – the urine and dung of livestock, the droppings of poultry, kitchen waste including bones. Where no livestock is kept and animal residues are not available, substitutes such as dried blood, slaughter-house refuse, powdered hoof and horn, fish manure, and so forth can be employed.

The waste products of the animal, in some form or another, are essential, if real humus is to be made for the following reasons.

a) *The verdict given by Mother Earth between humus made with animal residues and humus made with chemical activators such as calcium cyanamide and the various salts of ammonia has always been in favour of the former.* One has only to feel and smell a handful of compost made by these two methods to understand the plant's preference for humus made with animal residues. The one is soft to the feel, with the smell of rich woodland earth: the other is often harsh to the touch, with a sour odour.

Sometimes, when the two samples of humus made from similar vegetable wastes are analysed in a laboratory, the better report is produced by the compost made with chemical activators. When, however, they are applied to the soil, the plant speedily reverses the verdict of the laboratory.

Dr. Rayner refers to this conflict between Mother Earth and the analyst, in the case of some composts created for forestry nurseries:

> Full chemical analyses are now available for a number of these composts. In the initial stages of the work, a competent critic described one of them – since proved to be among the most effective – as 'an organic manure of comparatively little value', while another – since proved to be the least successful of all those tested – was claimed to be a 'first-class organic manure'.

The activator used in the first case was dried blood, in the second case an ammonium salt.

b) *No permanent or effective system of agriculture has ever been devised without the animal.* Many attempts have been made, but sooner or later they break down. The replacement of livestock by artificials is always followed by disease, the moment the original store of soil fertility is exhausted.

Where livestock is maintained, the collection of their waste products – urine and dung – in the most effective manner is important.

At Indore, the work cattle were kept in well-ventilated sheds with earthen floors and were bedded down daily with mixed vegetable wastes including about 5% (by volume) of hard material such as wood shavings and sawdust. The cattle slept on this bedding during the night, during which it was further broken up and impregnated with urine.

Next morning, the soiled bedding and cattle dung were removed to the pits for composting; the earthen floor was then swept clean and all wet places were covered with new earth, after scraping out the very wet patches. In this way all the urine of the animals was absorbed; all smell in the cattle sheds was avoided, and the breeding of flies in the earth underneath the animals was entirely prevented. A new layer of bedding for the next day was then laid.

Every three months, the earth under the cattle was changed. The urine-impregnated soil was broken up in a mortar mill, and stored under cover near the compost pits. This 'urine earth', mixed with any wood ashes available, served as a combined activator and base in composting.

In the tropics, where there is abundance of labour, no difficulty will be experienced in copying the Indore plan. All the urine can be absorbed, and all the soiled bedding can be used in the compost pits every morning.

In countries such as Britain and the USA, where labour is both scarce and dear, objection will at once be raised to the Indore plan. Concrete or pitched floors are the rule here. The valuable urine and dung are often removed to the drains by a water spray.

In such cases, however, the indispensable urine could be absorbed on the floors themselves through the addition to the bedding of substances such as peat and sawdust mixed with a little earth; or the urine could be directed into small bricked pits just outside the building, filled with any suitable absorbent material which is periodically removed and renewed. In this way, liquid manure tanks can be avoided. At all costs the urine must be used for composting.

Bases for neutralising excessive acidity

In the manufacture of humus, the fermenting mixture soon becomes acid in reaction. This acidity must be neutralised, otherwise the work of the micro-organisms cannot proceed at the required speed. A base is therefore necessary.

Where the carbonates of calcium or potassium are available in the form of powdered chalk or limestone, or wood ashes, these materials either alone, together, or mixed with earth, provide a convenient base for maintaining the general reaction within the optimum range (pH 7.0 to 8.0) needed by the micro-organisms which break down cellulose.

Where wood ashes, limestone, or chalk are not available, earth can be used by itself. Slaked lime can also be employed, but it is not so suitable as the carbonate. Quicklime is much too fierce a base.

Water and air

Water is needed during the whole of the period during which humus is being made. Abundant aeration is also essential during the early stages. If too much water is used the aeration of the mass is impeded, the fermentation stops and may become anaerobic too soon. If too little water is employed the activities of the micro-organisms slow down and then cease.

The ideal condition is for the moisture content of the mass to be maintained at about half saturation during the early stages; as near as possible to the condition of a pressed-out sponge. Simple as all this sounds, it is by no means easy in practice to maintain simultaneously the moisture content and the aeration of a compost heap so that the micro-organisms can carry out their work effectively. The tendency almost everywhere is to get the mass too sodden.

The simplest and most effective method of providing water and oxygen together is whenever possible to use the rainfall – which is a saturated solution of oxygen – and always to keep the fermenting mass open at the outset so that atmospheric air can enter and the carbon dioxide produced can escape.

After the preliminary fungal stage is completed and the vegetable wastes have broken down sufficiently to be dealt with by bacteria, the synthesis of humus proceeds under anaerobic conditions, under which no special measures for the aeration of the dense mass are either possible or necessary.

Pits versus Heaps

Two methods of converting the above wastes into humus are in common use. Pits or heaps can be employed.

Pits

Where the fermenting mass is liable to dry out or to cool very rapidly, the manufacture should take place in shallow pits; a considerable saving of water then results. The temperature of the mass tends to remain high and uniform.

Sometimes, however, composting in pits is disadvantageous on account of waterlogging by storm water, by heavy rain, and by the rise of the groundwater from below. All these result in a wet sodden mass in which an adequate supply of air is out of the question. To combat such waterlogging, the composting pits are:

1. Surrounded by a catch-drain, to cut off surface water.
2. Protected by a thatched roof where the rainfall is high, and heavy bursts of monsoon rain are the rule.
3. Provided with 'soakaways' at suitable points, combined with a slight slope of the floors of the pit towards the drainage corner.

Where there is a pronounced rise in the water table during the rainy season, care must be taken, in siting the pits, that they are so placed that there is no invasion of water from below.

Heaps

To save the expense of digging pits and to use up sites where excavation is out of the question, composting in heaps is practised. A great deal can be done to increase the efficiency of the heap by protecting the composting area from stormwater by means of catch-drains and by suitable shelter from wind, which often prevents all fermentation on the more exposed sides of the heap.

In temperate climates, heaps should always face the south, and wherever possible should be made in front of a south wall and be protected from wind on the east and west. The effect of heavy rain in slowing down fermentation can be reduced by increasing the size of the heap as much as possible. Large heaps always do better than small ones.

In localities of high monsoon rainfall such as Assam and Ceylon, there is a definite tendency to provide the heap or the pit with a grass roof so that the fermentation can proceed at an even rate and so that the annual output is not interfered with by temporary waterlogging. After a year or two of service, the roof itself is composted. In Great Britain thatched hurdles can be used.

Charging the heaps or pits

A convenient size for the compost pits (where the annual output is in the neighbourhood of 1,000 tons) is 30 feet by 14 feet, and three feet deep with sloping sides.

The depth is the most important dimension on account of the aeration factor. Air percolates the fermenting mass to a depth of about

18 to 24 inches only, so for a height of 36 inches, extra aeration must be provided. This is arranged by means of vertical vents, every four feet, made by a light crowbar as each section of the pit is charged.

Charging a pit 30 feet long takes place in six sections, each five feet wide. The first section, however, is left vacant to allow the contents to be turned. The second section is charged first.

A layer of vegetable wastes about six inches deep is laid across the pit to a width of five feet. This is followed by a layer of soiled bedding or farmyard manure two inches in thickness. The layer of manure is then sprinkled well with a mixture of urine earth and wood ashes, or with earth alone, care being taken not to add more than a thin film of about one-eighth of an inch in thickness. If too much is added, aeration will be impeded. The sandwich is then watered, where necessary, with a hose fitted with a rose for breaking up the spray.

The charging and watering process is then continued as before, until the total height of the section reaches five feet. Three vertical aeration vents, about four inches in diameter, are then made in the mass by working a crowbar from side to side.

The first vent is in the centre, the other two midway between the centre and the sides. As the pit is 14 feet wide and there are three vents, these will be 3′6″ apart. The next section of the pit (five feet wide) is then built up close to the first, and watered as before. When five sections are completed, the pit is filled. The advantages of filling a pit or making a heap in sections to the full height of five feet are:

1. Fermentation begins at once in each section and no time is lost.
2. No trampling of the mass takes place.
3. Aeration vents can be made in each completed section without standing on the mixture.

In dry climates, each day's contribution to the pit should again be lightly watered in the evening and the watering repeated the next morning. In this way the first watering at the time of charge is added in three portions:

1. At the actual time of charging.
2. In the evening after charging is completed.
3. Again the next morning, after an interval of twelve hours.

The object of this procedure is to give the mass the necessary time to absorb the water.

The total amount of water that should be added at the beginning of fermentation depends on the nature of the material, on the climate and on the rainfall. Watering, as a rule, is unnecessary in Great Britain.

If the material contains about a quarter by volume of fresh greenstuff, the amount of water needed can be considerably reduced. In rainy weather when everything is on the damp side, no water at all is needed. Correct watering is a matter of local circumstances and of individual judgement. At no period should the mass be wet; and at no period should the pit be allowed to dry out completely.

At the Iceni Nurseries in South Lincolnshire in Great Britain, where the annual rainfall is about 24 inches and a good deal of fresh green market-garden refuse is composted, watering the heaps at all stages is unnecessary. At Indore in Central India where the rainfall was about 50 inches, falling over about four months, watering was always essential except during the actual rainy season.

These two examples show that no general rule can ever be laid down as to the amount of water to be added in composting. The amount depends on circumstances. The water needed at Indore was from 200 to 300 gallons for each cubic yard of finished humus.

As each section of the pit is completed, everything is ready for the development of an active fungal growth, the first stage in the manufacture of humus. It is essential to initiate this growth as quickly as possible and then to maintain it. As a rule it is well established by the second or third day after charging. Soon after the first appearance of fungal growth, the mass begins to shrink and in a few days will just fill the pit, the depth being reduced to about 36 inches.

Two things must be carefully watched for and prevented during this first phase:

1. The establishment of anaerobic conditions caused generally by over-watering, or by want of attention to the details of charging; it is at once indicated by smell and by the appearance of flies attempting to breed in the mass. When this occurs, the pit should be turned at once.

2. Fermentation may slow down through lack of water. In such cases, the mass should be watered. Experience will soon teach what amount of water is needed at the time of charge.

Turning the compost

To ensure uniform mixture and decay and to provide the necessary amount of water and air for the completion of the aerobic phase, it is necessary to turn the material twice.

First turn. The first turn should take place between two and three weeks after charging. The vacant space, about five feet wide, at the end of the pit allows the mass to be conveniently turned from one end, by means of a pitchfork. The fermenting material is piled up loosely against the vacant end of the pit, care being taken to turn the unaltered layer in contact with the air into the middle of the new heap.

As the turning takes place, the mass is watered, if necessary, in the same manner as at the time of charging, with care being taken to make the material moist but not sodden with water. The aim should be to provide the mass with sufficient moisture to carry on the fermentation until the second turn. To achieve this, sufficient time must be given for the absorption of water. The best way is to proceed as at the time of charging, and add any water needed in two stages – as the turning is being done, and again next morning.

Another series of vertical air vents 3′6″ apart should be made with a crowbar as the new heap is being made.

Second turn. About five weeks after the initial charge, the material is turned a second time, but in the reverse direction. By this time the fungal stage will be almost over; the mass will be darkening in colour, and the material will be showing marked signs of breaking down. From now onwards, bacteria take an increasing share in humus manufacture, and the process becomes anaerobic.

The second turn is a convenient opportunity for supplying sufficient water for completing the fermentation. This should be added during the actual turning, and again the next morning to bring the moisture content to the ideal condition – that of a pressed-out sponge. It will be observed as manufacture proceeds that the mass crumbles, and that less and less difficulty occurs in keeping the material moist. This is due to two things:

1. Less water is needed for the fermentation.
2. The absorptive and water-holding power of the mass rapidly increase as the stage of finished humus is approached.

Soon after the second turn the ripening process begins. It is during this period that the fixation of atmospheric nitrogen takes place. Under favourable circumstances, as much as 25% of additional free nitrogen may be secured from the atmosphere.

The activity of the various micro-organisms which synthesise humus can most easily be followed from the temperature records. A very high temperature, about 65°C (149°F), is established at the outset, which continues with a moderate downward gradient to 30°C (86°F) at the end of 90 days.

This range fits in well with the optimum temperature conditions required for the micro-organisms which break down cellulose. The aerobic thermophylic bacteria thrive best between 40°C (104°F) and 55°C (131°F). Before each turn, a definite slowing down in the fermentation takes place; this is accompanied by a fall in temperature.

When the mass is remade, more thorough mixing and aeration occurs, and there is a renewal of activity during which the undecomposed part of the matter from the outside of the heap or pit is transformed. This activity is followed by a distinct rise in temperature.

The storage of humus

Three months after charging, the micro-organisms will have fulfilled their task, and humus will have been completely synthesised. It is now ready for the land.

If kept in heaps after ripening is completed, a loss in efficiency must be faced. The oxidation processes will continue. Nitrification will begin, resulting in the formation of soluble nitrates. These may be lost either by leaching during heavy rain, or they will furnish the anaerobic organisms with just the material they need. Such losses do not occur to anything like the same extent when the humus is 'banked', by adding it to the soil.

Freshly prepared humus is perhaps the farmer's chief asset, and must therefore be looked after as if it were actual money. It is also an important part of the livestock of the farm. Although this livestock can be seen only under the microscope, it requires just as much thought and care as the pigs or cows which can be seen with the naked eye.

If humus must be stored, it should be kept under cover and turned from time to time.

Output

The output of compost per year obviously depends on circumstances.

At the Institute of Plant Industry, Indore, where the supply of urine and dung was always greater than that of vegetable waste, 50 cartloads (each 27 c. ft.) of ripe compost, i.e. 1,350 cubic feet or 50 cubic yards, could be prepared from one pair of oxen. Had sufficient vegetable wastes been available, the quantity could have been at least doubled.

The work cattle at Indore were of the Malvi breed, about three-quarters the size of the average milking cow of countries such as Great Britain. The urine and dung of an average English cow or bullock, therefore, if properly composted with ample wastes, would produce about 60 cartloads of humus a year, equivalent to about 1,600 cubic feet or 60 cubic yards.

As the moisture content of humus varies from 30 to 60% during the year, it is impossible to record the output in tons unless the percentage of water is determined. The difficulty can be overcome by expressing the output in cubic feet or cubic yards. The rate of application per acre should also be stated as so many cubic feet or cubic yards. Two cubic yards of compost weigh about one ton.

In devising the Indore Process, the fullest use was made of agricultural experience, including that of the past. After the methods of Nature, as seen in the forest, the practices which throw most light on the preparation of humus are those of the East, which have been described by King, in *Farmers of Forty Centuries*.

In China, a nation of observant peasants has worked out for itself simple methods of returning to the soil all the vegetable, animal, and human wastes that are available. In doing so, a dense population has been maintained without any falling off in fertility.

Coming to the more purely laboratory-based investigations on the production of humus, two proved to be of great value in perfecting the Indore Process:

1. The papers of Waksman, in which the supreme importance of micro-organisms in the formation of humus was consistently stressed.

2. The work of H. Hutchinson and E. Richards on artificial fertilisers.

Waksman's insistence on the role of micro-organisms in the formation of humus, as well as on the paramount importance of the correct composition of the wastes to be converted, has done much to lift the subject from a morass of chemical detail and empiricism onto the broad plane of biology, to which it rightly belongs. Once it was realised that composting depended on the work of fungi and bacteria, the reform of the various composting systems which are to be found all over the world could be taken in hand.

The essence of humus manufacture is first to provide the organisms with the correct raw material, and then to ensure that they have suitable working conditions. Hutchinson and Richards come nearest to the Indore Process, but two fatal mistakes were made:

1. The use of chemicals instead of urine as an activator in breaking down vegetable wastes.
2. The patenting of the ADCO process.

Urine consists of the drainage of every cell and every gland of the animal body, and contains not only the nitrogen and minerals needed by the fungi and bacteria which break down cellulose, but all the accessory growth substances as well.

The ADCO powders merely supply factory-made chemicals as well as lime – a far inferior base to the wood ashes and soil used in the Indore Process. It focuses attention on yield, rather than on quality. It introduces into composting the same fundamental mistake that is being made in farming; namely, the use of chemicals instead of natural manure.

Further, the patenting of a process (even when, as in this case, the patentees derive no personal profit) always places the investigator in bondage; he becomes the slave to his own scheme. Rigidity takes the place of flexibility, and progress becomes difficult, or even impossible. The ADCO process was patented in 1916; in 1940 the method, to all intents and purposes, remains unchanged.

The test of any process for converting the waste products of agriculture into humus is flexibility and adaptability to every possible set of conditions. It should also develop, and be capable of absorbing, new knowledge and fresh points of view as they arise.

Finally, it should be suggestive and indicate new and promising lines of research.

If the Indore Process can pass these tests, it will soon become woven into the fabric of agricultural practice. It will then have achieved permanence and will have fulfilled its purpose – the restitution of their manurial rights to the soils of this planet.

In the next four chapters (2.2 to 2.5), we will investigate the progress made during the last eight years towards this ideal.

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2.2 *Practical Applications of the Indore Process*

After the first complete account of the Indore Process was published in 1931, the adoption of the method at a number of centres followed very quickly. The first results were summarised in a lecture which appeared in the *Journal of the Royal Society of Arts* of December 8th, 1933. About 2,000 extra copies of this lecture were printed and distributed during the next two years.

By the end of 1935 it became evident that the method was making very rapid headway all over the world: an increasing stream of interesting results were reported. These were described in a second lecture on November 13th, 1935, which was printed in the journal of the society of November 22nd, 1935. This lecture was then republished in pamphlet form. In all 6,425 extra copies of this second lecture have been distributed.

During 1936 still further progress was made, a brief account of which appeared in the *Journal of the Royal Society of Arts* of December 18th, 1936; 7,500 copies being printed.

Two translations of the 1935 lecture have been published. The first in German in *Der Tropenpflanzer* of February 1936, the second in Spanish in the *Revista del Instituto de Defensa del Café de Costa Rica* of March 1937.

These papers did much to make the Indore Process known all over the world and to start a number of new and active composting centres. The position, as reached by July 1938, was briefly sketched in a paper which was published in the *Journal of the Ministry of Agriculture* of Great Britain of August 1938.

In this and succeeding chapters, an attempt will be made to sum up progress to the time of going to press. It will be convenient in the first place to arrange this information under crops.

Coffee

The first centre in Africa to take up the process was the Kingatori Estate near Kyambu, a few miles from Nairobi, where work began in February 1933. By the purest accident, I saw the first beginnings of composting at this estate. This occurred in the course of a tour around Africa, which included a visit to the Great Rift Valley.

As I was about to start from Nairobi on this expedition, Major Belcher, the manager of Kingatori, called upon me and said that he had just been instructed by Major Grogan, the proprietor of the estate, to start the Indore Process and to convert all possible wastes into humus.

He asked me to help him and to discuss various practical details on the spot. I gave up the tour to the Great Rift Valley and spent the day on the Kingatori Estate instead, where it was obvious from the general condition of the bushes and the texture of the soil that a continuous supply of freshly made humus would transform this estate, which I was told was typical of the coffee industry near Nairobi.

In a letter dated September 19th, 1933, Major Belcher reported his first results as follows:

> I have 30 pits in regular use now, and am averaging five tons of ripe compost from each pit. This will give me a dressing of 3.5 tons per acre *per annum* and should, I think, gradually bring the soil into really good condition.
>
> I have already dressed 30 acres, but it is a little early to see any result. It is 30 acres of young four-year-old coffee, bearing a heavy crop. At the moment it is looking splendid, and if it keeps it up until the crop is picked in December and enables the trees to bear heavily again next year, there will be no doubt in my mind that the compost is responsible. Young trees with a big crop are very apt to suffer from die-back of the primaries, and light beans and no crop in the following year. There is no sign of this at present.
>
> I have had many interested visitors, and the Nairobi bookseller has to keep sending for more copies of *The Waste Products of Agriculture*.
>
> The District Commissioner at Embu has taken up the process extensively with the double purpose of improving village sanitation and the fertility of the soil. In fact, he started it some time before we did.
>
> I understand that it will shortly be made illegal to export goat and cattle manure from the native reserves, in which

> case your process will be taken up by most of the European farmers in the Colony. One very influential member of the coffee industry remarked to me that he thought your process would revolutionise coffee-growing, and another said that he considered it was the biggest step forward made in the last ten years.

Two years later, he sent me a second report in which he stated that during the last 28 months 1,660 tons of compost, containing about 1.5% of nitrogen, had been manufactured on this estate and applied to the land. The cost per ton was 4s. 4d. – chiefly the expense involved in collecting raw material. The work in progress had been shown to a constant stream of visitors from other parts of Kenya, the Rhodesias, Uganda, Tanganyika, and the Belgian Congo. Major Belcher has lost count of the actual numbers.

This pioneering work has done much more than weld the Indore Process into the routine work of the estate. It has served the purpose of an experiment station and a demonstration area for the coffee industry throughout the world. Many new centres followed Kingatori. The rapid spread of the method is summed up by Major Grogan in a letter dated Nairobi, May 15th, 1935:

> You will be glad to know that your process is spreading rapidly in these parts and has now become recognised routine practice on most of the well-conducted coffee plantations. The cumulative effect of two years on my plantation is wonderful. I have now established all round my pits a large area of elephant grass for the purpose of providing bulk, and we have made quite a lot of pocket money by selling elephant grass cuttings to the countryside. I am now searching for the best indigenous legumes to grow in conjunction with the elephant grass and am getting very hopeful results from the various Crotalerias and Tephrosias which I have brought up from the desert areas of Taveta. They get away quickly and so hold their own against the local weeds.

Major Grogan, in referring to the spread of the Indore Process in East Africa, has omitted one very material factor; namely, his personal share in this result. He initiated the earliest trial on the Kingatori Estate and has always insisted on the method having a square deal in Kenya. In Tanganyika the influence of Sir Milsom Rees has led to similar results.

This example of the introduction and spread of the Indore Process on the coffee estates of Kenya and Tanganyika has been given in detail for three reasons:

1. It was one of the earliest applications of the Indore method to the plantation industries.
2. It is typical of many other similar applications elsewhere.
3. It first suggested to me a new field of work during retirement, in which the research experience of a lifetime could be fully utilised.

Kenya and Tanganyika are only two of the coffee centres of the world. The largest producer is the New World. Here satisfactory progress has been made following the publication in the *West India Committee Circular* of April 23rd, 1936, of a short account of the Indore Process. This led to important developments, first in Costa Rica and then in Central and South America, as a result of a Spanish translation by Senor Don Mariano Montealegre of my 1935 lecture to the Royal Society of Arts, to which reference has already been made.

This was widely read in all parts of Latin America: the lecture drew attention to the vital necessity of organic matter in the production of coffee in the New World.

During the next two years, no less than seven Spanish translations of my papers on humus were published in the *Revista del Instituto de Defensa del Café de Costa Rica*. In January 1939 a special issue of the *Revista* entitled *En Busca del Humus* (*In Quest of Humus*) appeared. This was devoted to a collection of papers describing the Indore Process and the various developments of the last eight years.

The marked response of coffee to humus in Africa, India, and the New World suggested that the crop would prove to be a mycorrhiza-former. A number of samples of the surface roots of coffee plants were duly collected in Travancore, Tanganyika, and Costa Rica and sent home for examination.

In all cases they showed the mycorrhizal association.

Tea

The East African results with coffee naturally suggested that something should be done with regard to tea – a highly organised plantation industry with the majority of the estates arranged in large groups, controlled by a small London Directorate largely recruited from the industry itself.

The problem was how best to approach such an organisation. In 1934, my knowledge of tea and the tea industry was of the slightest: I had never grown a tea plant, let alone managed a tea plantation. I had only visited two tea estates, one near Nuwara Eliya in Ceylon in 1908 and the other near Dehra Dun in 1918.

I had, however, kept in touch with the research work on tea. While I was debating this question, Providence came to my assistance in the shape of a request from a mutual friend to help Dr. C. Harler (who had just been retrenched when the Tocklai Research Station, maintained by the Indian Tea Association, was reorganised in 1933) to find a new and better opening, if possible one with more scope for independent and original work.

I renewed my acquaintance with Dr. Harler and suggested that he should take up the conversion into humus of the waste products of tea estates. He was very interested and shortly afterwards (August 1933) accepted the post of Scientific Officer to the Kanan Devan Hills Produce Co. in the High Range, Trayencore.

On taking up his duties in this well-managed and highly efficient undertaking, Dr. Harler secured the active interest of the then General Manager, Mr. T. Wallace, and set to work to try out the Indore Process on an estate scale at his headquarters at Nullatanni, near Munnar. No difficulties were met with in working the method. Ample supplies of vegetable wastes and cattle manure were available, the local labour took to the work, and the estate managers soon became enthusiastic.

On receipt of this information, I made inquiries from Dr. H. Mann, a former Chief Scientific Officer of the Indian Tea Association, as to whether the livewires among the London Directorate of the tea industry included anybody likely to be particularly interested in the 'humus question'.

I was advised to see Mr. James Insch, one of the Managing Directors of Messrs. Walter Duncan & Company. At Mr. Insch's request an illustrated paper of instructions for the use of the managers of the Duncan Group was drawn up in October 1934, and 250 copies were printed. The Directors of other groups of tea estates soon began to consider the Indore Process, and 4,000 further copies of the paper of instructions were distributed. By the end of 1934, 53 estates of the Duncan Group in Sylhet, Cachar, the Assam Valley, the Dooars, Terai, and the Darjeeling District had made and distributed sample lots of humus, about 2,000 tons in all. At the time of writing, December 1939, the estates of the Duncan Group alone expect to make over 150,000 tons of humus a year.

Similar developments have occurred in a number of other groups, notably on the estates controlled by James Finlay & Co., who have never lost the lead in manufacturing humus which naturally followed from the pioneering work done by Dr. Harler in Travancore. A good beginning has been made. The two strongest groups of tea estates in the East have become 'compost-minded'.

It is exceedingly difficult to say exactly how much humus is being made at the present time on the tea estates of the British Empire. It is possible only to give a very approximate figure. In April 1938, Messrs. Masefield and Insch stated:

> It is probably no exaggeration to say that today a million tons of compost are being made annually on the tea estates of India and Ceylon, and this has been accomplished within a period of five years.

Since this was written, the tea estates of Nyasaland and Kenya have also taken up the Indore Process with marked success.

These developments have been accompanied by a considerable amount of discussion. Two views have been, and are still being, held on the best way of manuring tea.

One school of thought, which includes the tea research institutes, considers that as the yield of leaf is directly influenced by the supply of combined nitrogen in the soil, the problem of soil fertility is so simple as to reduce itself to the use of the cheapest form of artificial manure – in this case, sulphate of ammonia.

This view is naturally vigorously supported by the artificial fertiliser interests. The results obtained with sulphate of ammonia on small plots at Tocklai and Borbhetta are triumphantly brought forward to clinch the argument which amounts to this: that tea can be grown on a conveyor-belt lubricated by chemical fertilisers.

The weaknesses of such an argument are obvious. These small plots do not represent anything in the tea industry: they only represent themselves. It is impossible to run a small plot or to manufacture and sell its produce as a tea plantation is conducted. In other words the small plot is not practical politics. Again, land like Tocklai and Borbhetta which responds so markedly to sulphate of ammonia must be badly farmed, otherwise artificials would not prove so potent.

The tendency all the world over is that as the soil becomes more fertile, artificials produce less and less result, until the effect ceases altogether. Bad farming and an experimental technique which will not hold water are poor foundations on which to found a policy. The use of replicated and randomized plots, followed by the higher mathematics in interpreting the results of these small patches of land, can do nothing to repair the fundamental unsoundness of the Tocklai procedure. It stands self-condemned.

Further, the advocates of sulphate of ammonia for the tea plant seem to have forgotten that a part at least of the extra yield obtained with this manure may be due to an increase in soil acidity. Tea, as is well known, needs an acid soil, and sulphate of ammonia increases acidity.

The humus school of thought takes the view that what matters in tea is quality, and a reserve of soil fertility such as that created by the primeval forest. This can only be obtained by freshly prepared humus made from vegetable and animal wastes, and by the correct use of shade trees, green-manure crops, and the prevention of soil erosion.

The moment the tea soils can be made really fertile, the supply of nitrogen to the plant will take care of itself, and there will be no need to waste money in securing the fleeting benefits of artificials. The problem, therefore, of the manuring of tea is not so much the effect of some dressing on the year's yield, but the building up of a store of fertility.

In this way the manurial problem and the stability of the enterprise as a going concern become merged into one. It is impossible to separate the profit and loss account and the balance-sheet of a composting programme, because the annual dressings of humus influence both.

It will be interesting to watch the results of this struggle in a great plantation industry. At the moment a few of the strongest and most successful groups are taking up humus, and spend little or nothing on artificials. Other companies, on the other hand, are equally convinced that their salvation lies in the use of cheap chemical fertilisers. Between these two extremes, a middle course is being followed – humus supplemented by artificials.

Mother Earth, rather than the advocates of these various views, will in due course deliver her verdict.

Can the tea plant itself throw any light on this controversy, or is it condemned to play a merely passive role in such a contest? Has the tea bush anything to say about its own preference? If it has, its representations must at the very least be carefully considered. The plant or the animal will answer most queries about its needs if the question is properly posed, and if its response is carefully studied.

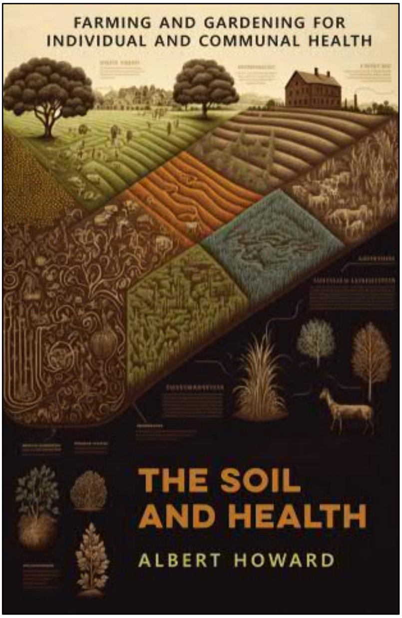
During the early trials of the Indore Process, it became apparent that the tea plant had something very interesting to communicate on the humus question. Example after example came to my notice, in which such small applications of compost as five tons to the acre were at once followed by a marked improvement in growth, in general vigour and in resistance to disease.

Although gratifying, in one sense these results were somewhat disconcerting. If humus acts only indirectly, by increasing the fertility of the soil, time will be needed for the various physical, biological, and chemical changes to take place. If the plant responds at once, some other factor besides an improvement in fertility must be at work. What could this factor be?

In a circular letter issued on October 7th, 1937, to correspondents in the tea industry, I suggested that the most obvious explanation of any sudden improvement in tea, observed after one application of compost, is the effect of humus in stimulating the mycorrhizal relationship which is known to occur in the roots of this crop.

In the course of a recent tour to tea estates in the East, I examined the root system of a number of tea plants which had been manured with properly made compost, and found everywhere the same thing – numerous tufts of healthy looking roots associated with rapidly developing foliage, and twigs much above the average. Both below and above ground, humus was clearly leading to marked well-being.

When the characteristic tufts of young roots were examined microscopically, the cortical cells were seen to be literally overrun with mycelium and to a much greater extent than is the rule in a serious infection by a parasitic fungus. Clearly, the mycorrhizal relationship



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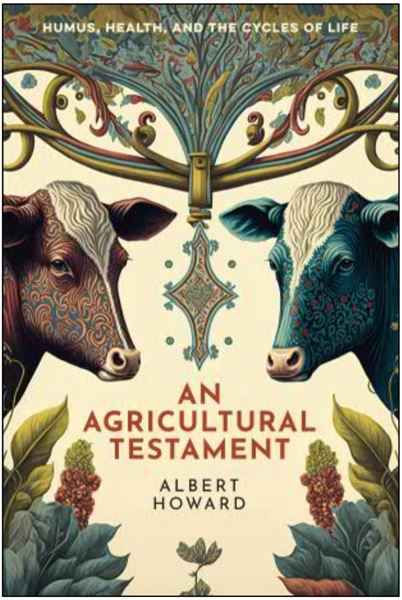

An Agricultural Testament

Albert Howard

A new edition of Howard's classic work from the early days of the organics movement in Britain.

Howard's discoveries and methods, and their implications, are given in detail. They are of enormous usefulness to gardeners and farmers, and to anyone who may be interested in the history and the problems of land use.

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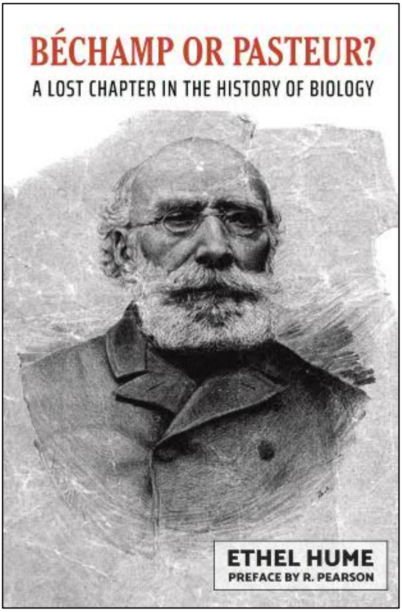

Béchamp or Pasteur?

Ethel Hume / Robert Pearson

Pearson's *Pasteur: Plagiarist, Imposter* was originally published in 1942 and is a succinct introduction to both Louis Pasteur and Antoine Bechamp, and the background to the troubled relationship that they shared for their entire working lives. Ethel Hume documents the evidence in detail, so that there is no escaping the obvious conclusion – Pasteur was a fraud.

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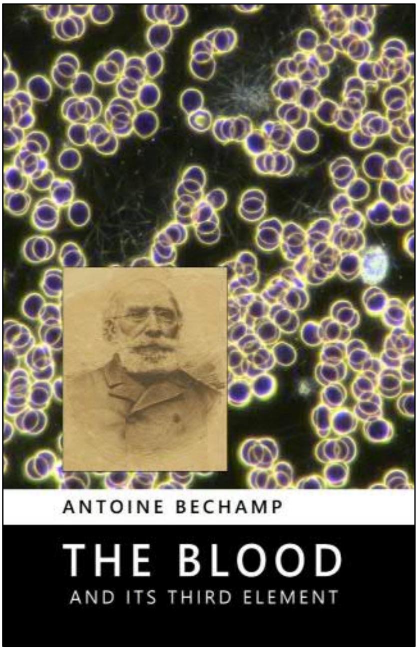

The Blood and its Third Element

Antoine Béchamp

There is no single cause of disease. The ancients knew this. Béchamp proved it with meticulous research, and was written out of history for his trouble. The relevance of his work to the dilemmas that plague the modern medical world remains to this day unrealized by mainstream science and medicine.

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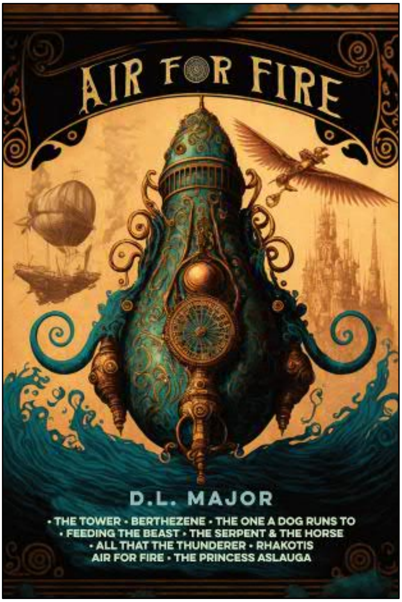

Air for Fire

D.L. Major

A collection of short stories and poetry by the author of *The Day of the Nefilim*. While *The Nefilim* was a meandering trip through some of the world's great conspiracy theories, *Air for Fire* is a collection of short tales that happen in every timeline but this one. Shameless historical revisionism.

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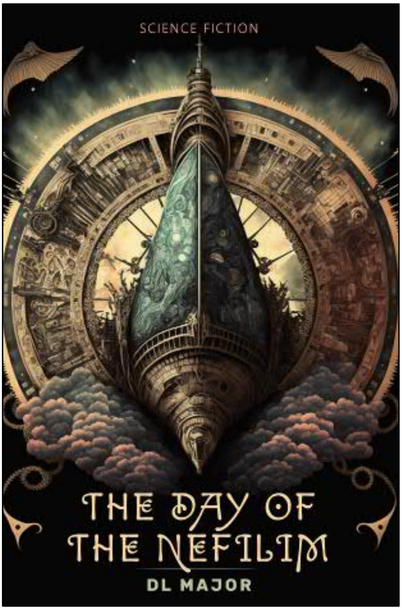

The Day of the Nefilim

D.L. Major

"...one of the best SF novels I have read since I began reading. I read it straight through, in one sitting. Yeah, that's right, I did not put the book down until I finished reading it. Couldn't. Well done, David. Keep writing. Can't wait to read your next book… you would make Robert Anton Wilson proud, and Douglas Adams smile." – *reader review*

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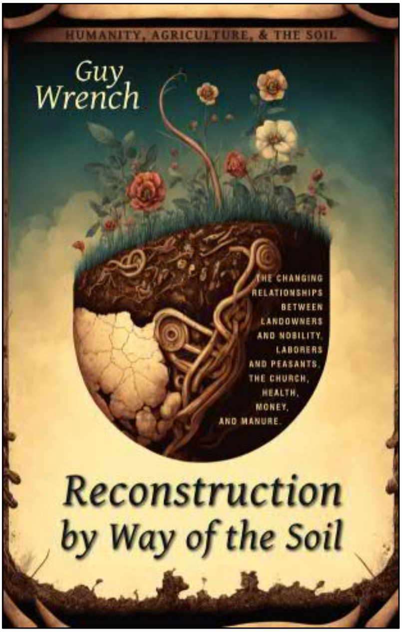

Reconstruction by Way of the Soil

Dr Guy Wrench

Includes case studies from Ancient Rome, nomadic societies, medieval England, Africa and Egypt, the West Indies, Russia, Australia and the USA to show that nothing is more important than the relationship between civilization and the soil. The way that the soil is treated has brought about both the rise and fall of civilizations.

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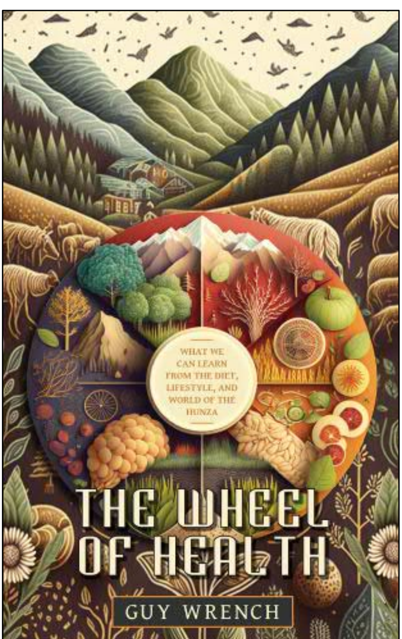

The Wheel of Health

Dr Guy Wrench

The Hunza of northern Pakistan were famous for their extraordinary vitality and health. Dr Wrench argues that in part at least, this is because their food was not made 'sophisticated', by the artificial processes typically applied to modern processed food. How these processes affect our food is dealt with in great detail in this book. What Dr Wrench uncovered in his researches goes deeper than just food, though. It's about water.

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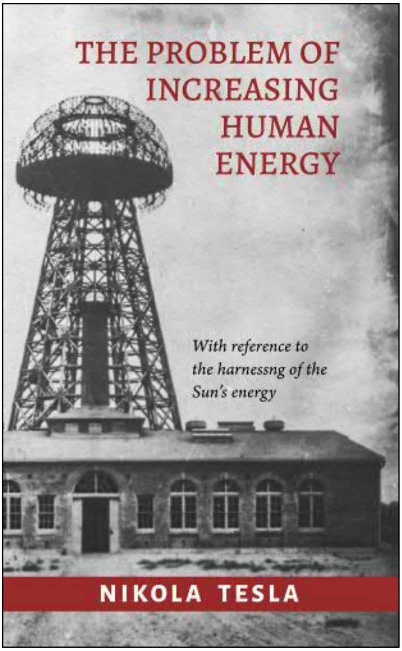

The Problem of Increasing Human Energy

Nikola Tesla

Contains Tesla's thoughts on humanity's relationship with the universe, and also his explanation of the technological wonders embodied in his work.

This text was first published in *Century Illustrated Magazine* in June 1900.

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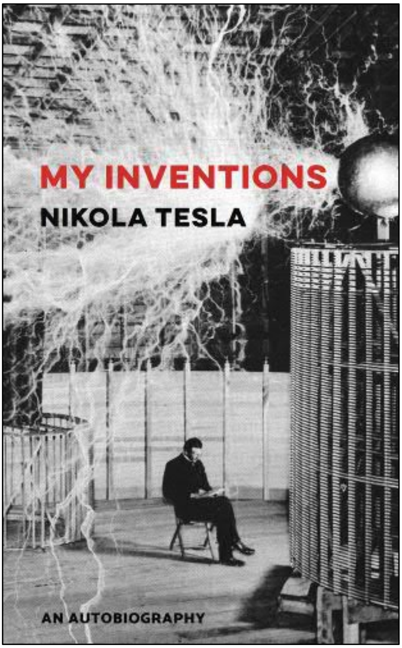

My Inventions

Nikola Tesla

Not only is this book an invitation to meet one of the greatest minds of the last century, and to hear him talk about his inventions;
it is also a chance to get to know Tesla as a person, as the book is filled with anecdotes of his early life.

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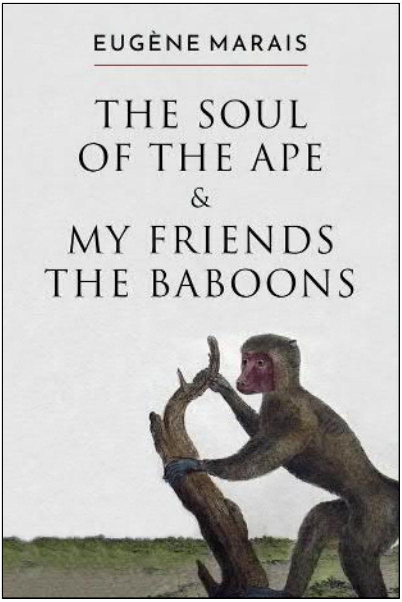

The Soul of the Ape

Eugène Marais

Includes two works by Marais written after his period spent living among a troop of baboons in the South African veldt. *My Friends* was written for a newspaper readership. *The Soul of the Ape* was the more serious scientific document. The excellent introduction by Robert Ardrey was part of the 1969 edition, and adds greatly to an appreciation of the importance of this text.

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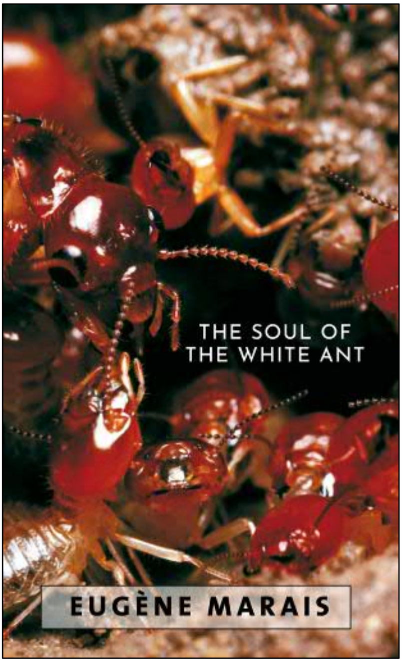

The Soul of the White Ant

Eugène Marais

The amazing results of a long, close study of the lives of termites. Eugène Marais compares the infrastructure of a termitary to that of the human body. Writing from the heart, this scientific author who is also a poet instills a wonder in the reader, of the incredible intricacies of nature, in a light-hearted, easily readable manner.

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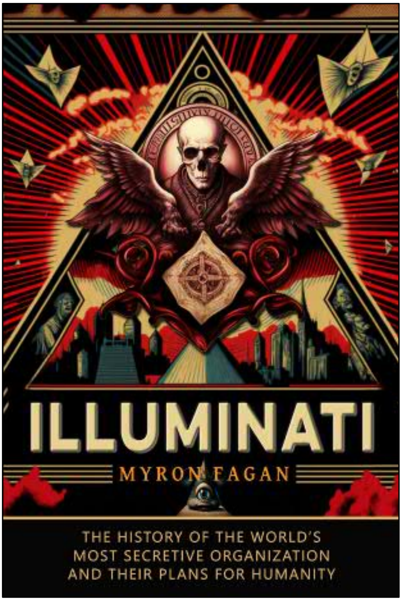

Illuminati

Myron Fagan

This book describes how the Illuminati became the instrument of the Rothschilds to achieve a One World Government, and how every war during the past two centuries has been instigated by this group. This is an historical text with names, dates, organizations and mode of operations, all exposing the octopus gripping the world today.

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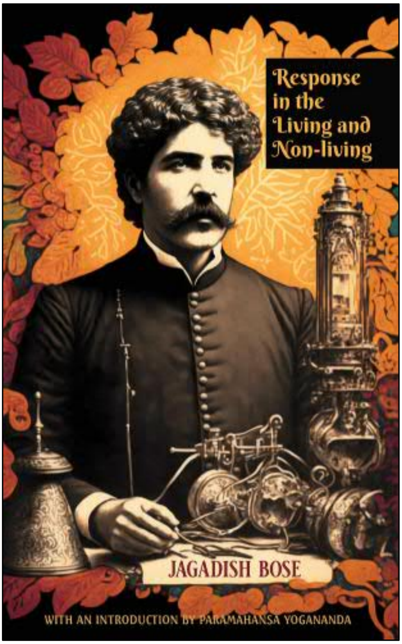

Response in the Living and Non-living

Jagadish Bose

This is one of the great Indian scientist's earlier works. His experiments showed that in the entire range of responses – regardless of whether the subject is metallic, plant or animal – the responses are identical. The living response, in all its diverse modifications, is a repetition of the responses seen in the inorganic. *Everything is alive.*

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Ten Acres is Enough

Edmund Morris

Recently we have seen a great back-to-the-land movement, with many young professional people returning to small scale farming; thus it is useful to read about someone who did exactly the same thing in 1864. In that year, Edmund Morris and his family gave up their business and city life for a farm of ten acres, where they made a go of mixed farming, and then wrote a book about it.

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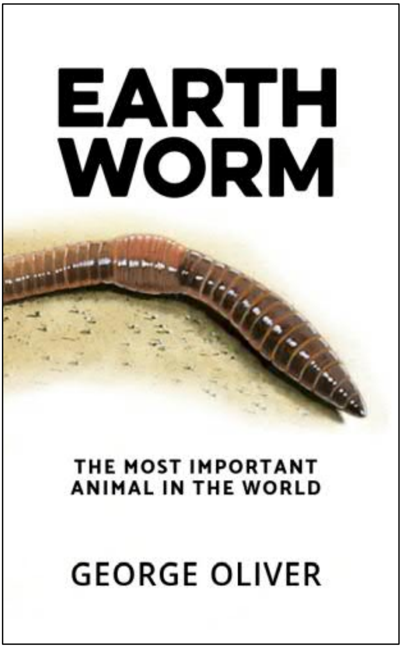

Earthworm

George Oliver

The author returns the reader to a time and methodology where people took responsibility for what they did and what they produced. In this world of spiraling food prices, huge landfills, diminishing food supplies, loss of topsoil, and water pollution, the reader is reminded that the world's most important animal could well be the humble earthworm.

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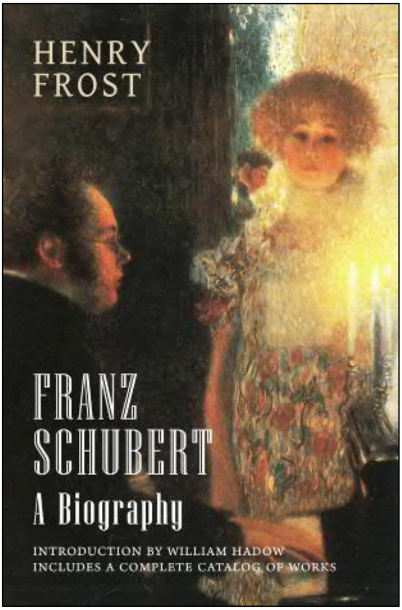

Franz Schubert – a Biography

Henry Frost

"With faith man steps forth into the world. Faith is far ahead of understanding and knowledge; for to understand anything, I must first of all believe something. Faith is the higher basis on which weak understanding rears its first columns of proof; reason is nothing but faith analysed."
– *Franz Schubert*

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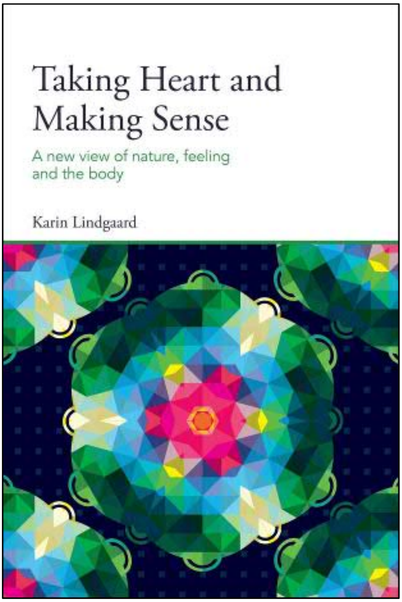

Taking Heart and Making Sense

Karin Lindgaard

What do animals feel? How do living systems become conscious?

The author takes on these and many more questions about the natural world and human experience, helping us to understand our feelings and emotions, and our sense of meaning in life. Lingaard takes readers on a conceptual adventure across psychology, philosophy and cognitive science.

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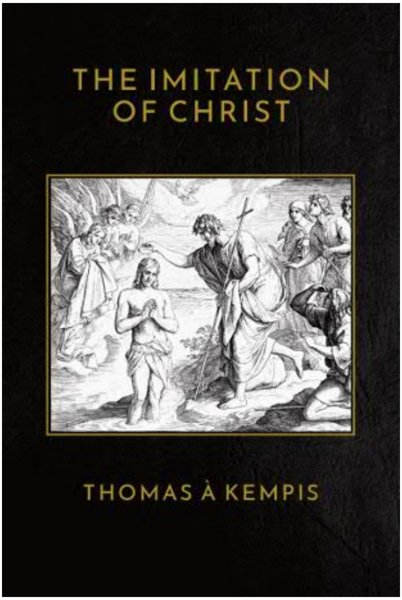

The Imitation of Christ

Thomas à Kempis

A new edition, extensively illustrated with prints by Julius Schnorr von Carolsfeld and featuring many bible passages from the RSVCE Bible. This text has long been a treasure trove for Catholics around the world. With its beautiful illustrations and carefully selected Bible passages, this new edition brings timeless wisdom to life like never before.

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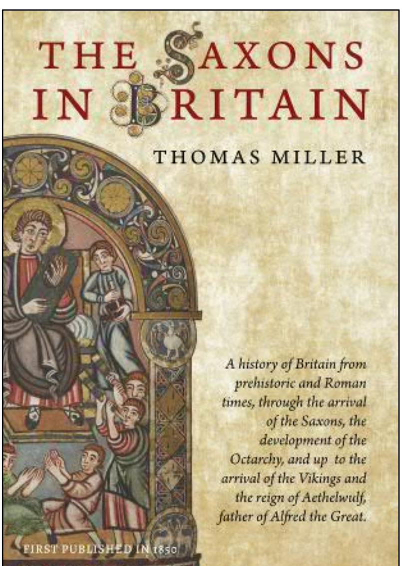

The Saxons in Britain

Thomas Miller

An illustrated history of Britain from prehistoric and Roman times, through the arrival of the Saxons, the development of the Octarchy, and up to the arrival of the Vikings and the reign of Aethelwulf, father of Alfred the Great.

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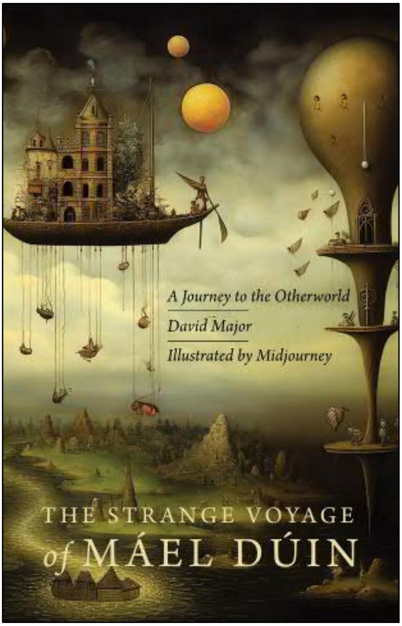

The Strange Voyage of Máel Dúin

David Major & Midjourney

A new edition of one of the great stories of Irish mythology. It is extensively illustrated in full color by Midjourney, at the time of publication the leading AI illustration tool.

A collaboration between human and artificial intelligence, the Strange Voyage of Máel Dúin is a legendary tale from Gaelic literature that holds a significant place in the traditions of myth and history. It recounts the extraordinary maritime journey of the heroic Máel Dúin and his companions as they embark on a perilous quest.

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