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Agricultural Chemistry

REVISED EDITION

AGRICULTURAL CHEMISTRY

AGRICULTURAL CHEMISTRY

A FAMILIAR EXPLANATION OF THE CHEMICAL PRINCIPLES INVOLVED IN THE OPERATIONS OF THE FARM

BY

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With a Preface

BY THE LATE

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CONSULTING CHEMIST TO THE ROYAL AGRICULTURAL SOCIETY

REVISED, EXTENDED, AND BROUGHT UP TO DATE

BY

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AUTHOR'S PREFACE TO LATEST EDITION.

IF a sustained demand for a book may be taken as a measure of its success, I have no reason to be dissatisfied with the reception accorded to this one, as, apart from the large number purchased when first published, there has been a steady sale ever since, the pages having been stereotyped to admit of indefinite multiplication; and for which I again take the opportunity of expressing my acknowledgments.

I take it as a further compliment that it has had not only a large but a wide circulation, having been well read by all classes of agriculturists, including the smaller men who are supposed to be non-readers, but who, thus induced to commence, may be assumed, in many cases at least, to continue their reading of general agricultural literature to the profit of themselves as well as of the community. I may also add I have met with it in the hands of town residents who had no connection with agriculture, and in general libraries.

The advance of Agricultural Chemistry having rendered a revision of the book necessary, this has now been done with the assistance of my nephew, Mr. A. E. Sibson, who has carried out the greater part of the work with great pains and patience. He is not only conversant with recent chemico-agricultural topics and an able and experienced analyst, but, like myself, has a real liking for the work beyond any professional advancement it may bring; and as to myself, I can honestly say that during the whole course of my chemical work I have always found it a source of pleasure apart from profit. I look upon Agriculture as one of the worthiest, as it is certainly amongst the most useful, of human pursuits; and upon Chemistry as one of its most valuable allies, as well as an attractive occupation for its own sake.

I may take the opportunity of expressing my regret that the cloud of depression from which Agriculture has suffered during recent years has fallen so heavily on some of its followers, but trust that the worst is now past, and that a better time for all concerned has really begun. I may also, perhaps, be allowed to express the hope, now that circumstances are more favourable, that a larger number of our best class of young men will take up Agriculture in this country with more spirit than hitherto, too many of whom go half over the world to follow similar pursuits, but with harder work and less reward, not to speak of less civilized surroundings.

Besides a large number of corrections and smaller additions, new articles or notices have been written on the following subjects:—

New Introductory Remarks.	Mixed Foods.
Nitrification.	Albuminoid ratio.
Water as Rain.	Dairying.
Sewage and similar Manures.	Home-made Manures.
Water hygienically considered.	Reverted Phosphate.
Ensilage.	Slag Phosphate.
Assimilation of Nitrogen.	Adulteration Bill.
Raw Phosphates.	Nitrogenous Materials.
Cakes and purchased Foods.	Value of Manures.

All of the above will be found in the Index, which has been extended. The examples of manures, raw phosphates, cakes, etc., are nearly all new, being the results of recent analyses made in the ordinary way for clients; while some of the appended remarks have appeared in my annual reports. It will be noticed that in these tables the older form of chemical expression has been retained, as it is the one most generally understood in agricultural and commercial circles.

ALFRED SIBSON.

23, ST. MARY AXE, E.C.

AUTHOR'S PREFACE TO NEW EDITION (1867).

THE improvements made in Artificial Manures, and their extended employment in Agriculture, even since the publication of the present work, have rendered desirable a revision and extension of the articles on this important subject; and as the other portions of the work do not at present need any material alterations, it was decided to add such new matter in the form of an Appendix. In this I have endeavoured to supply a fair account of the more important artificial manures now in use, with such observations on their successful and economical employment as have been suggested by a more extended experience of their composition and practical effects, necessarily gained in my present position as public analyst. As I have had the gratification of finding this volume a book of frequent reference amongst all classes of agriculturists, I also take the opportunity of supplying a complete Index, to render it more useful in this way.

I may also take the opportunity of expressing my grateful acknowledgments for the very flattering reception accorded to the present work, which has reached a circulation, both in this country and on the continent of Europe (having been translated into at least five languages) and America as well as India and the Colonies, probably greater than any former work on the subject.

ALFRED SIBSON.

PREFACE.

ALTHOUGH we possess several excellent works on Agricultural Chemistry, I have long felt the want of a treatise sufficiently comprehensive, and at the same time sufficiently explicit and correct, to be put with advantage into the hands of a person ignorant of the first chemical principles, and unaccustomed to scientific language. This want, I think, will be supplied by Mr. Sibson's treatise.

There are several excellent works which, like Johnson's *Agricultural Chemistry*, would render a new treatise on Agricultural Chemistry superfluous if they embodied all the recent chemico-agricultural discoveries, and could be obtained at a price sufficiently low to secure an extensive circulation. There are other meritorious works on Agricultural Chemistry, which are written by authors who evidently in great measure are unacquainted with the practical wants of persons interested in farming pursuits.

Mr. Sibson's treatise certainly possesses the merit of being written by a gentleman who for several years has resided in the country, and has had many opportunities of becoming personally acquainted with the wants of the farmer, and has taken an active part in several important investigations that have been carried on in my laboratory. Mr. Sibson also has had extensive experience for noticing the peculiar difficulties that present themselves to the unscientific reader of works on Agricultural Chemistry. I believe, also, the natural arrangement of the subject-matter in the treatise—an arrangement which is fully explained in the first introductory chapter, will be found as novel as it is practically useful, and conscientiously recommend Mr. Sibson's work to the considerate notice of the public.

AUGUSTUS VOELCKER.

ROYAL AGRICULTURAL COLLEGE,
CIRENCESTER, Sept. 1858.

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AGRICULTURAL CHEMISTRY.

CHAPTER I.

INTRODUCTION.

AMONGST the causes that have led to the present advanced position of the agriculture of this country, not the least prominent is the assistance it has received at the hands of science. While nearly every branch of natural science has more or less contributed to the general improvement of agriculture, chemistry, undoubtedly, occupies a high rank amongst the means that have helped to advance this most important branch of human industry.

As it is the peculiar province of chemistry to teach us the composition of all existing objects, to make us acquainted with the materials of which they are composed and the changes these materials undergo when exposed to different influences, it is not surprising that this, above all other natural sciences, is the one most concerned in the operations of daily life, or is the one most capable of affording information on all points connected with the natural and artificial changes constantly proceeding in all the constituents of the earth. And as chemistry is ever ready to impart, when properly solicited, any amount of this kind of knowledge, it cannot be wondered that nearly every branch of human industry has at different times received benefit from the hints and suggestions of this most useful and practical science.

Agriculture is peculiarly susceptible of improvement from chemistry, inasmuch as many of the practical operations performed by the farmer are essentially chemical processes; and at the present time, when the use of artificial manures is nearly indispensable in the farm routine, a knowledge of at least the general principles of chemistry is almost imperative in the farmer who expects to avail himself of all the appliances of modern agriculture; and all should do this to the best of their ability now that competition with the foreigner has become so important a factor in our calculations, for it is clear that only by the production of first class goods, whose quality may be depended on, can we hope successfully to meet this, and thus help in removing the depression which has so long affected agriculture. It is to be most sincerely hoped that certain slight improvements in some branches may be regarded as indications of the merely temporary character of the cloud.

Amongst the numerous contributions of chemistry to agriculture, perhaps the most important is the introduction of artificial manures into the system of cultivation; and were this the only practical service conferred by chemistry, it would, on this account alone be entitled to a high place in our estimation, since it is to an extended use of these materials that we must chiefly look for the means of increasing the produce of our land to meet the wants of a constantly multiplying population. Not only does chemistry teach us the best means of preparing and applying these important fertilizing agents, but it points out to us sources of them which we should otherwise have entirely overlooked. At the present time we manufacture valuable manures from substances that formerly would never have been dreamt of as sources of indispensable plant food. For instance, there are found in certain localities beds of minerals resembling, in their external properties, ordinary rocks and stones; but by chemical analysis they are found to contain a compound called by chemists phosphoric acid; this compound is an essential constituent of nearly all kinds of cultivated produce. In grain, roots, hay, etc., we find considerable quantities of phosphoric acid, which has been derived from the soil on which this produce has been raised. The soil always contains phosphoric acid, but often in deficient quantity, or so combined that plants can but slowly avail themselves of it; we endeavour to increase the readily assimilable quantity by adding manures, most of which contain this substance in greater or less abundance. On the discovery of the presence of phosphoric acid in the minerals above noticed, the thought would naturally occur to us to make use of them as a source of this valuable fertilizing compound. But a difficulty presents itself: it is also found that the phosphoric acid occurring in these minerals exists in an insoluble stony form, utterly incapable of being assimilated by the delicate roots of plants. Hence its addition in this form to the soil is followed by no good result if applied unground.

When extremely finely divided by careful and continued grinding, some varieties of phosphates, as South Carolina, bone ash, Thomas' phosphate, etc., may be used on certain soils with better results than was formerly supposed; soils containing much organic matter with a sufficient supply of moisture, which seems very essential to success, are especially adapted for such treatment, but under most circumstances this cannot be considered a thoroughly satisfactory method of providing phosphate.

Here chemistry again comes to our assistance: it not only leads us to discover an unexpected source of a scarce material, but further directs how to proceed in changing the insoluble useless form in which we find it into a state that will admit of its use as manure. By following these directions the difficulty is overcome, and we are able to prepare a valuable manure from useless stones. The minerals we allude to are called apatite, phosphorite, coprolite, etc., and at the present time are largely employed as the raw material from which the well-known manure called superphosphate of lime is prepared. With nearly every other point of agricultural economy chemical principles are more or less intimately connected. Hence, by understanding these principles, the practical man will often be able to act with certainty in cases where, otherwise, having no rule to guide him, he can proceed only with hesitation.

Amongst the numerous branches into which the science of chemistry has necessarily become divided by its rapid extension during the present century, agricultural chemistry is undoubtedly amongst the most important, and at the present time is certainly one of the most active and flourishing of these divisions. As in the economy of manufactures the division of labour is found to be so conducive to a high state of excellence of the manufactured produce, so, in the science of chemistry, its marvellous extension during the present and two or three preceding generations is chiefly to be attributed to the fact of each of its divisions having been taken up by particular chemists, who, by directing their energies to that portion of the subject best suited to their tastes, have raised it to a high degree of excellence, and thus have contributed to the enlargement of the mass of knowledge at present comprised under the head of general chemistry. At the present time several distinguished chemists are satisfied to devote the best of their energies to the subject of agricultural chemistry, which, in so far as its connection with the general welfare of the community is concerned, apart from its intrinsic merits, is certainly one of the finest of human pursuits.

As most of the operations of agriculture are an extension or adaptation of those of Nature, it follows that all the chemical changes involved in the phenomena of germination, growth, development of seeds, and final decay of plants, as well as the more important changes belonging to animal life, must be included in the chemistry of agriculture. This subject will also include the changes that accompany the alteration in the quality of land, either for the worse, by exhaustion or mismanagement, or for the better, as in the reclamation of waste lands and the restoration of those whose fertility has become impaired by culture.

To everyone who takes an interest in the operations of Nature, the development of every sort of agricultural produce in our fields and homesteads must be a source of wonder and delight. For instance, what can be more interesting than the growth of a wheat crop? We see the seed placed in the ground; in a short time young plants appear above the surface; the seed that had been preserved so long in an inactive state, when exposed to the influence of moisture, warmth, and air in the soil, germinates; or, in other words, the spark of vitality that had lain dormant so long in the seed, is awakened, and expends its first efforts in the production of an infant plant, which, so soon as it reaches the daylight, is able to provide for itself, and collect the requisite food for its future nourishment from the surrounding air and soil. Opinions appear to differ as to the length of time a seed may be kept before sowing and yet retain its power of germinating; some seem to think this property may be retained during a vast number of years—a view which others consider very doubtful. By the imperceptible yet rapid increase of substance, the crop acquires strength and vigour, produces blossoms, and finally seeds, which duly ripen and wait to be gathered. What can be more beautiful than a field of wheat in this condition? Every one must admire such a scene, whether he regard it as a natural object of great beauty or as the source of our daily bread.

In contemplating such a scene we naturally reflect on the composition and origin of the produce before us. We know that the grain of wheat contains flour, which, when properly prepared, will become bread, capable of nourishing and strengthening our bodies. Whence comes this flour? The plants have gradually increased in substance from the period when they first appeared above the ground, and have fully developed their seed or grains, but whence has been derived the necessary material? It must obviously come from the earth, or the air, or the moisture, or from each of these sources ; but what marvellous changes must take place before these materials can become the vegetable produce in question! Such a scene has an additional interest to the farmer, who, looking upon the crop as the means by which he is to pay his rent and remunerate himself for the labour and anxiety expended in its cultivation, and that of several preceding crops, will reflect more deeply than the casual observer on the circumstances connected with its growth. He knows that the produce before him has been largely produced at the expense of the soil. That some essential constituents have been directly obtained from the soil is evidenced by the well-known fact that the soil will require manure and rest before it can produce such another crop. But even the farmer, although better acquainted with the practical details of the matter, if unacquainted with chemistry, is equally at a loss to account for the changes proceeding in the materials under his hands ; he cannot tell what the wheat removes from the soil, and why it should not grow with equal vigour in the same field a second year, or why a crop of another kind will. Again, he cannot explain the action of the manure he uses, what it is in the manure that imparts fertility to a soil, and why one kind of manure more particularly benefits one kind of crop. Further, it is well known that particular soils, irrespective of their general fertility, are best fitted for the growth of certain kinds of crops ; for instance, clover, pease, and other plants belonging to the tribe called leguminous plants, flourish most luxuriantly on lime soils, and languish, or even refuse to grow, in soils deficient in lime. Again, clay soils are known to be most favourable to the growth of wheat.

On these and numerous other points connected with the economy of agriculture chemistry is able to enlighten us, and in most cases to afford us a clear explanation of the changes attending the various operations going forward on the farm, as well as of the principles that regulate those changes. It will tell us, for instance, the composition of the wheat-plant, and point out the constituents of its seeds on which their nutritive value depends. It will also show us the sources of those constituents and enable us to perceive how the presence of certain bodies in the soil affects the growth of the crop.

At the same time we must not fall into the error of expecting too much from chemistry; it must be borne in mind that, although agricultural chemistry has greatly advanced, much yet remains to be done, and many of its regions are still unexplored. Moreover, there are matters connected with the simplest operations of Nature far beyond the power of science to explain; such matters will probably ever remain as at present—profound mysteries to us.

While chemistry makes us acquainted with the character of the materials of which all objects surrounding us are made, and teaches us the laws that regulate the movements of these materials, she does not for a moment attempt to explain or account for these laws; but by pointing them out to us and exhibiting their effects, she greatly aids us in comprehending the part they perform in Nature.

With a knowledge of chemistry we are better able to appreciate the grandeur of those natural laws which, having been established at the creation by an all-wise Providence, control the movements of all the materials of the earth and insure their co-operation in the series of changes necessary for the preservation of the system of Nature.

To describe in a familiar manner the more important chemical principles involved in the operations of agriculture is the object of this little book. In doing this we have thought it advisable to begin by explaining the more striking points of what may be called the Chemistry of Nature, or that division of the subject which treats of the properties and uses of those materials of the earth which take part in the growth of plants and the nourishment of animals, whether growing in a wild or natural state, or reared and cultivated by man in the practice of agriculture.

We therefore first call attention to the atmosphere ; then to the earth or soil ; next to water, pointing out the respective constituents of each of these natural groups of substances, and briefly describe their more prominent characters, dwelling more particularly on those most concerned in the practical operations of the farm. We next trace the formation in the organization of the plant from materials derived from the earth, air and water, of those vegetable compounds which afterwards become the food of man and animals. This is followed by a consideration of the more striking characters of all the ordinary cultivated crops and the circumstances that affect their growth. After proceeding to explain the further changes these compounds undergo in the bodies of animals when consumed as food, such as the conversion of vegetable food into the more highly organized animal products, such as butter, cheese, mutton, beef, etc., we give an exposition of the changes accompanying the various operations employed in agriculture for the improvement or alteration of the texture and quality of the land, whether by mechanical or chemical means. In this division, referring more strictly to the chemistry of agriculture, we propose to introduce the important subject of manures, to describe the characteristic properties of natural or home-made farmyard manure, as well as the more numerous "artificials". Amongst the artificials we specially notice bone-dust, guano, superphosphate of lime, and other artificial manures commonly employed by the farmer. We propose to point out their several uses, modes of application, and the qualities that affect their value ; also their comparative merits and the adulterations to which they are subject. Farmyard manure, in consideration of its superior importance, is treated at greater length, and the chemical changes this manure undergoes by different modes of treatment, described somewhat in detail. Many of the facts mentioned in connection with farmyard manure had been but recently discovered when this book was first written, and up to that time had been published only in the papers referred to in the chapter devoted to this subject.

Looking over the foregoing remarks after a considerable interval, we do not think there is much to alter, bearing in mind the character of the book, as addressed more especially to those supposed to have no previous knowledge of the subject.

Concerning the materials more immediately touching the farmer's pocket as a buyer, viz., manures and cakes, or his raw materials, so to speak, and their connection with the produce of the farm, a few further remarks may be offered.

Chemistry is not only of great assistance in enabling the farmer to obtain these commodities of good quality and on the most favourable terms, by means of analysis, as considered under the heads of manures and cakes, but it also enables him to keep a better check upon them through the various metamorphoses they undergo in the operations of the farm, and enables him to see more distinctly whether they are properly applied to good purpose, as intended, or whether any portion of them goes to waste, as too often happens. In a factory—say, a cotton mill—the material enters in the form of bales of raw cotton, and leaves as finished calico, or what not, and at every stage of the manufacture the cotton can be clearly perceived, its quantity traced, and any waste easily discovered. But it is not so on the farm, where the above articles, or rather their constituents, take many shapes, and may easily be lost without our knowing how; an illustration will perhaps make this clear.

If a sovereign be dissolved in nitro-hydrochloric acid, as is frequently done by manufacturers of photographic chemicals, we get, after suitable processes, a beautiful crystalline compound called auric chloride or trichloride of gold. It is true it has the colour of its parent metal but no other point of resemblance, and no one who did not know would imagine it contained gold ; even a burglar would pass it by as unworthy of his attention. This salt is deliquescent, or attracts moisture from the air, and if left exposed would soon become liquid, and might easily be wiped away as a few drops of spilt liquid. It is thus very soluble in water, and if exposed to rain would soon be washed away and lost ; but supposing care were taken to preserve the whole of this salt, even though mixed with much water, in which it would of course be invisible as a clear fluid, we could by suitable means recover the whole of the gold which was present in the coin.

A similar change takes place during the growth of a crop of roots to which we apply superphosphate : the plants take up the phosphoric acid, and it becomes part and parcel of the roots when developed ; but no one would suppose, unless he knew, that part of the superphosphate had passed into this shape. Again, linseed cake is a comparatively expensive article, as it is rich in nitrogen in a solid, tangible form, not to speak of the phosphates and potash of lesser value it contains. Average good linseed cake contains about $5\frac{1}{2}$ to 6 per cent. of ammonia (nitrogen equal to), equivalent to 22 to 24 per cent. of sulphate of ammonia; it is therefore nearly one-fourth as rich in nitrogen as this article, which is the most concentrated form of ammonia commonly met with. When this cake is given to stock, a portion, depending on the kind of animal fed, is retained as increase, and takes the form of flesh or meat, as well as internal organs or offal, but another and larger portion passes through the animal and is obtained in the manure ; of course a similar change proceeds with the roots and other food given to the animal, but it is perhaps more striking in the case of cake, which is a very rich food and has to be directly paid for.

The nitrogen is found both in the solid and liquid portion of the manure; the latter is the more important, since it is present in a soluble and invisible form, which easily runs away and is lost if not received in water-tight receptacles, or by sufficient absorbents, and especially if, as in yard feeding, the manure is exposed not only to the natural rain, which is bad enough, but often also to the drainage from roofs, as explained in treating of farmyard manure. This is one reason why we usually get more benefit from our cake if given to animals fed on the land, as in sheep-folding, where there is little chance of loss in the manure and which is one of the best and most economical means of improving poor land.

Although it is not possible to recover our nitrogen from cake as completely as our gold in the illustration, we may take it that where no loss is allowed as above, the manure produced will be the richer by the quantity of cake consumed after deducting the amount retained as animal increase, and the crops to which it is applied will be benefited the same as if so much nitrogen were bought and applied in the form of any chemical manure, although the visible bulk of the manure may be no greater than if no cake were used.

The above described experiment also illustrates another point well worthy of note. We may recover the whole of our gold from the sovereign, but it will obviously not be a sovereign; all the elaborate processes of minting will be requisite to convert this gold into a coin of the realm. It is in this fabrication or fashioning that there is so marked a distinction between the manufactured articles of man and natural or organized products, the latter being infinitely more complex than our highest efforts in this direction. Thus, although it is possible by an elaborate series of processes to produce a gold coin from gold in any shape, the production of even the simplest food constituent cannot be brought about by any mechanical or chemical means that we are masters of. Not a single article of food or food component can be artificially prepared. It is true glucose sugar is now made on a large scale from grain, but the starch must be grown to begin with; it is even possible to get sugar and alcohol from rags, but here again the cellulose or fibre must be grown to start with. Up to the present, food of any and every sort can only be produced either directly or indirectly through the agency of the vegetable kingdom, the actual changes taking place in the cells of the plant—Nature's laboratory, whose mysteries we are constantly trying to unravel, but at present know but little about. Again, the element of time is a notable feature in all such natural processes, which are sufficiently marvellous and admirable notwithstanding their slowness, and would not be possible without it, at least short of a miracle.

This comparatively long time of production distinguishes agriculture from other kinds of manufacture, so to speak, and is a serious drawback from a commercial point of view, and is probably one reason why commercial men are shy of it, except as an amusement. In a factory, for instance, at times of pressure, it is possible to increase the output in a given time by taking on more men or increasing our plant, but little can be done in this way in agriculture. We have but one spring and summer in the year, and these not to be depended on, and if from any cause the seasons are missed we can only wait for the next year. It is true there is now an endeavour to lessen this drawback by growing more catch crops and by cultivating an early maturity in our stock, and, in fact, the whole tendency of high farming is in this direction; and it should not be forgotten that by liberal manuring our crops may develop almost imperceptibly even during cold weather, until by a favourable change they are enabled to push on quicker than when not so prepared, and are thus enabled to take better advantage of favourable weather to produce a heavier crop.

Finally, it may be noted that this putting together or construction of food components, or what corresponds to the item of labour in a factory, is effected by Nature herself in our fields, the work of the farmer consisting mostly in giving her an opportunity so to act under the most favourable circumstances, at least this is what we should strive for. But Nature not only thus manufactures, so to speak, the crops of the farm out of the raw materials we supply as manures, but also contributes the larger part herself, chiefly as water and the carbon dioxide of the atmosphere. An instance in illustration of this important fact may be taken from a root crop—say, a ton of swedes—this will contain about :—

	lbs.
Water	2,004
*Albuminous compounds . .	30
Carbonaceous principles . .	164
Fibre	28
Mineral matter	14
	2,240 = 1 ton.

* Containing nitrogen . . .	4.8.

The water is equal to about 200 gallons, and this deducted gives the actual food, or dry matter as it is termed, although it should be understood that even this water is water of constitution, or part and parcel of the roots which could not be developed or exist as such without it. The nitrogen includes that added as manure as well as some derived from the soil contributed from natural sources ; the same may be said of the mineral matter, which includes the phosphoric acid and potash. Deducting the whole of these for the sake of simplicity from the dry matter, we get 217 lbs., or nearly 2 cwt., of feeding material derived from the atmosphere. From this we ought perhaps to deduct the fibre, which, although necessary to the structure of the plant, is not of much value as food.

The food so obtained consists mostly of the carbonaceous principles or carbo-hydrates, such as starch, sugar, pectin, etc., which may be regarded as combinations of carbon and water, these being supplied *ad libitum* to all growing plants, the quantity they get being only limited by their ability to assimilate them, and this is to a great extent dependent on the amount of manure we supply, and the care bestowed on the general cultivation ; in other words, the proportion of food constituents thus obtainable from free sources is in an increasing ratio to the vigour of their growth. We have thus a direct incentive to do our utmost to assist Nature in this way, both in the interests of ourselves as cultivators, as well as of the community, as consumers, and we may depend she will ultimately reward us according to our deserts.

CHAPTER II.

THE ATMOSPHERE.

Physical Properties of the Atmosphere.

The atmosphere being invisible, most of us naturally know much less of the general characters of the air than we do of the earth, water, and other more material parts of the globe. With the exception of the disturbed condition of the air that we call wind, it possesses no positive quality that compels us to recognize its presence, as we do that of the earth and other natural objects, which make themselves known to us through the sense of sight ; but since the air cannot be recognized by our sight, we are unable to judge of its qualities by any of the ordinary means of comparison.

We are, however, made aware of the presence of the air when its effects are exhibited to us in some of the simple occurrences of everyday life ; as, for instance, when we make use of a pair of bellows to urge a fire, or move a fan backwards and forwards, and in a still more striking manner when we encounter a high wind. In each of these cases the resistance we meet with plainly convinces us of the substantial quality of the air. Again, on filling a bottle with water by dipping it under the surface, we notice that the water does not enter the bottle until the air has escaped in a series of bubbles ; or if we hold the bottle perpendicularly with its mouth downwards, and in this position immerse it under the surface of the water, the water will not enter, simply because the space in the bottle is already occupied with air ; and in this case the air cannot escape to make room for the water, as it usually does.

By these and numerous other simple operations we may satisfy ourselves that the air is indeed a substance, notwithstanding it is an invisible one.

The air or atmosphere forms a layer of light matter immediately above, and resting upon, the solid surface of the earth. In this light matter we, and every object we look upon, are immersed ; it envelops us on every side, and fills every space that in common language is said to be empty. Before proceeding to state of what this matter consists, or the part it performs in the economy of nature, let us briefly relate its physical or mechanical properties.

The air is a transparent, invisible substance, destitute of taste and smell, and permanently elastic, and moveable in every direction. Viewed in masses, it possesses a slight blue colour—the beautiful blue tint that often pervades the further objects in a landscape, is due to this colour of the air.

Since the air is a substance, it follows it must also possess weight. This is found to be the case. By suitable instruments the air can be weighed and its weight determined. A cubic foot of air weighs 527 grains, or about an ounce and a quarter, or is 715 times lighter than water. Now, as the air extends upwards to a great height, and every part of it possesses weight, it is evident that it must press upon the earth with considerable force. This force or weight can also be determined, and the entire weight of the atmosphere ascertained. The air presses upon the whole surface of the earth with as much force as would be exerted by a covering of water thirty-two feet deep, or a layer of quicksilver about thirty inches deep. Hence, a column of air of the entire height of the atmosphere, that is, from the surface of the earth to as far upwards as it extends, weighs the same as a column of water of the same size but only thirty-two feet high, or a column of quicksilver only thirty inches high. The actual weight of the atmosphere, or the force with which it presses upon the earth's surface, is about 15 lbs. on every square inch. The reason we do not feel this weight is because of the property of the air, called its "mobility", or the power of its particles to move in any direction. By this provision the downward pressure, or weight of the air, is diverted and distributed over every side and on every part of the objects exposed to it ; for instance, the weight pressing down upon our bodies is sustained by a corresponding weight pressing upwards, and the weight pressing upon one side of us is counterbalanced by the air pressing with an equal force on the opposite side. For this reason we remain perfectly unconscious of this prodigious weight of the atmosphere ; it is, however, instantly displayed, if by any means the air is removed from one side of an object, when the full weight of the air is exerted on the opposite side.

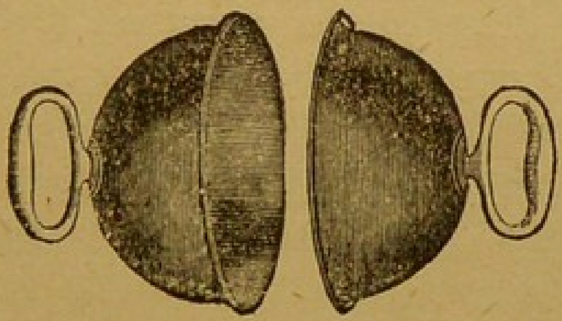
Several interesting experiments can be shown for proving the weight of the air, but since the branch of natural science we are now considering is not intimately connected with the subject, we need not enter any further into the physical properties of the air.*

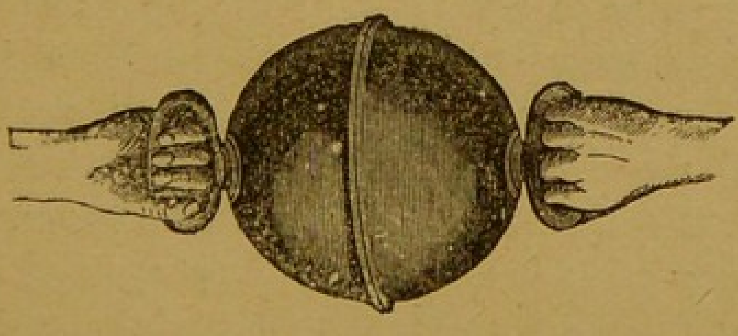
In conclusion, we may remark that several useful instruments in daily use depend for their action upon the weight of the air ; for instance, the lift-pump and the barometer, or weather-glass, are instruments of this sort. The latter

* We must, however, describe one simple experiment that in a most striking manner exhibits the weight of the air. A hollow brass globe of about six

particularly deserves notice, since, in addition to its being a most valuable instrument to the farmer, mariner and others, whose well-being is often influenced by the weather, it affords us the best proof of the weight of the air. It also shows the slight variations to which this weight is subject; and as these variations are indicative of certain atmospherical phenomena, as wind, rain, etc., its action as a foreteller of the weather is explained. A nearer approximation to the truth in this respect will be obtained if the readings in several districts are compared. When the barometer is moving rapidly we expect much atmospheric disturbance and may know that the larger mass of air above a neighbourhood,

inches in diameter is made in two pieces that fit accurately together; each piece is provided with a handle attached to its centre. These two hemispheres can be taken apart at pleasure, and are not fastened together in any way; if, however, the two halves are put together, and the air removed from the interior of the globe by means of a stopcock, not shown in the figure, the weight of the atmosphere is exerted upon the outside, and the two halves are firmly pressed together with such force that two men are unable to pull them apart.





This experiment excited a great amount of admiration when first exhibited by its inventor, Otto von Guericke, of Magdeburg, in Germany, in the year 1680.

shown by the height of the mercury, will tend to become distributed over a district where the glass is low.

The Materials of which the Atmosphere is Composed.

Having shown by the above statements that the air is a substance, we now proceed to consider what kind of substance it is, what materials it is composed of, and the connection between these materials and animal and vegetable life. We propose to do this in as simple a manner as possible, and to leave out all scientific terms and expressions, except those which, having no familiar substitutes, we are obliged to make use of.

All the materials found in the air belong to a class of substances called gases. The air, then, is a mixture of gases. Let us begin by explaining what a gas is. All the materials belonging to our globe are in either a solid, liquid, or gaseous condition. Those having the latter form are sometimes subdivided into gases and vapours, but in reality there is no essential difference between a gas and a vapour ; so that we may consider all materials of which the various natural objects are made to belong to one or other of these three classes. Every one naturally becomes acquainted with a great number of the solids and several of the liquids belonging to the earth, but comparatively few of us are acquainted with the different gases of the earth. This is because solids and liquids make themselves known to us through the sense of sight.. The differences between them are easily perceived, and we instinctively recognize their individual characters. But the case is different with gases. Although the number of gases is large, few of us are acquainted with any of them. It is because their individual characters are not so strikingly displayed as those of the more material solids and liquids, and, consequently, we cannot by our unaided senses distinguish between them. All gases resemble more or less the air we breathe. They are all transparent and all very much lighter than either solids or liquids. Yet the differences amongst themselves are very great in their appearance and qualities ; and, especially in their chemical characters they differ most widely. For instance, while the majority of gases are colourless and invisible, some of them possess beautiful colours. There is a green gas, a red gas, and a violet-coloured gas. Many of them are inodorous, others possess pungent smells, others again abominable and poisonous odours. While some of the gases are much heavier than the air, a few are considerably lighter. Thus we perceive there is almost as great a variety even in the physical properties of gases as there is in those of the more substantial solids and liquids.

Further, there are two great classes of gases :

1. Simple or elementary gases, *i.e.*, aëriform substances that consist of one kind of matter only.

2. Compound gases, or aëriform bodies consisting of several materials, into which they may be separated by suitable means.

The number of gases known to chemists is very great ; but, fortunately for those persons who take an interest in the materials of the earth only in so far as their connection with animal and vegetable life is concerned, only few gases have to be noticed. Usually not more than five or six gases are found in a free or uncombined state. And here we may remark that most gases are not a class of bodies permanently different from the solids and liquids of the earth. A gas must be regarded as a peculiar shape —a greatly expanded, enlarged condition, that certain bodies have the power of assuming under peculiar circumstances.

It need scarcely be repeated that all the gases usually found in the air are devoid of taste, colour and smell, and are transparent and invisible. The atmosphere consists chiefly of two gases, called respectively oxygen and nitrogen.

These two gases form the bulk of the air, all the other constituents occupying but a small space. Of these two gases nitrogen is the more abundant, forming four parts out of every five; the remaining fifth is oxygen. The other constituents are carbonic acid gas, water in the form of gas or vapour, with much smaller and varying quantities of nitric acid and ammonia.

The composition of the atmosphere may thus be stated :—

COMPOSITION OF THE ATMOSPHERE.

(One Hundred Parts.)

	By Weight.	By Measure.
Oxygen	23.01	20.81
Nitrogen	76.99	79.19
	100.00	100 00

Carbonic Acid in 10,000 parts of Air.	
Largest quantity	5.74
Smallest quantity	3.15

Water in 100 parts of Air at—	Parts of Water.
30 deg. Fahrenheit	.41
50 " "	.80
80 " "	2.01
90 " "	2.70
100 " "	3.60

We now proceed to describe each of these constituents, its qualities, and the part it performs in nature.

PROPERTIES OF OXYGEN.

Oxygen is the most abundant material of the earth. It not only forms, as we have seen, one-fifth part of the entire atmosphere, but it forms a still larger proportion of the bulk of water, rocks, earths and minerals. In water, eight parts of every nine are oxygen—the vast quantity of water on the globe, in the shape of seas, rivers, lakes, and the great oceans themselves, all containing oxygen in this proportion. Again, in rocks, minerals, and soils, oxygen forms a large proportion, averaging about one-half of their weight; thus, one-half of all the rocks and solid materials of the globe consists of oxygen. It is no less abundant in the animated world. In animals, oxygen forms three-fourths of their weight; in vegetables, four parts out of every five consist of oxygen. Thus we see oxygen is the chief material of which the entire globe is made. We also learn by the above statements that oxygen exists in three different mechanical forms: as a liquid in water; as a solid in rocks, stones, and soils; and in a state of gas in the air. In this latter condition it is free or uncombined, and in this form we shall now describe it.

Oxygen gas is the active principle of the air. Most of the properties we usually ascribe to the air are, in reality, due to the oxygen it contains. For instance, we say that a fire or a candle will not burn without air, but it is the oxygen only of the air that the fire or candle requires. Again, animals are said to require air in the vital process of breathing, but it is the oxygen only that takes any part in the operation. On exposure to the air, metals—as iron, zinc, etc.—are known to get corroded or rusted. Here, again, it is the oxygen that corrodes or rusts them, although it would appear that water and carbonic acid must be present to assist in the change, for iron remains untarnished in perfectly dry air. And so, in most natural operations, it is the oxygen that induces the changes observed to follow exposure to the air.

Oxygen in a pure state closely resembles the air in its external properties; it is equally colourless and free of smell. Oxygen when liquified is said to possess a blue colour, and the suggestion has been made that the blue appearance of the sky is due to this gas being a constituent of the atmosphere; others hold this colour to be produced by the presence of a condensed form of oxygen called ozone. It is characterized by possessing all the chemical properties of the air in a much higher degree. In other words, everything that the air does oxygen does far more quickly and violently. In air, iron rusts slowly and imperceptibly; in oxygen, it burns with such violence that in a few seconds a piece of iron is entirely converted into oxide. Brimstone, that burns in the air with pale blue flame, scarcely visible by daylight, in oxygen burns with a brilliant light. A candle recently blown out is re-lighted if placed in oxygen gas. In fact, every material that burns in the air burns with increased brilliancy and violence in oxygen. Oxygen acts in a similar manner on animal life, the process of breathing being hastened to such an excessive degree as to produce death.

The effects of combustion, respiration, rusting of iron, etc., either in pure oxygen or in the air, are produced by the oxygen combining with the materials concerned in the operation. Wherever a fire is seen the oxygen is combining with the fuel; when iron is converted into rust the oxygen combines with the metal. Thus the distinguishing property of free or uncombined oxygen is its affinity, as chemists say, or its inclination, if the term may be used, to combine with all bodies in a condition to receive it. The phenomena of combustion, respiration, decay, putrefaction, etc., are all consequences of this property of oxygen; and in all these operations compounds of oxygen are formed. These compounds are called by chemists oxides. These oxides are very abundant in nature: thus most of the materials belonging to the soil, as sand, lime, etc., are mixtures of oxides or consist of oxygen gas combined with various other substances.

Properties of Nitrogen.

The too exciting oxygen is diluted and its activity properly restrained by the more abundant but indifferent substance nitrogen. As we have seen, four parts out of every five parts of air consist of nitrogen, hence there is an enormous quantity of nitrogen on the globe; but, unlike oxygen, its presence is almost confined to the atmosphere and the animal and vegetable kingdoms, and seems to form but a small part of the mineral portion of the earth.

Nitrogen in a pure state cannot be distinguished by our unaided senses from common air, or even oxygen ; it is equally devoid of all striking qualities when in a separate or unmixed condition. It differs from oxygen in its effects upon burning bodies. Oxygen, as we have seen, accelerates the combustion of burning bodies, as a candle or taper ; nitrogen instantly extinguishes them. Hence we may readily distinguish it from oxygen, and by the same test also from the air. An animal is killed by immersion in nitrogen, not from any poisonous qualities of the gas, but simply because it deprives the animal of the indispensable oxygen ; the taper is extinguished from the same cause.

Nitrogen, as found in the air, is remarkable for its inactive, indifferent qualities, its only purpose in this state seeming to be to curb the impetuosity of its too excitable companion—oxygen. Were we unacquainted with nitrogen in any other form, we might pronounce it to be almost destitute of chemical properties ; but such would be a very unfair estimation of the characters of nitrogen, since it forms, when in combination with other bodies, compounds remarkable for the essential functions they perform in the growth of plants and the nourishment of animals. The fact is, nitrogen seldom combines directly with other substances as oxygen does, but nearly always does so in a roundabout manner. Hence compounds of nitrogen are not formed when substances are exposed to it in the air, as they are of oxygen under the same circumstances.

Nitrogen in a solid form is present in all cultivated plants, as grasses, roots, wheat, etc., and particularly in those parts of the plants distinguished for their nourishing qualities when used for the food of men or animals. The grain of oats, barley and wheat all contain nitrogen.

Also in the bodies of animals nitrogen occurs in great abundance. Animal matters of nearly all descriptions contain a large proportion of nitrogen: in flesh, hair, feathers, bone, etc., there is a great deal of this substance. Hence the flesh of our domestic animals in the form of animal food supplies us with large quantities of this solid or combined nitrogen; indeed, most kinds of food, and particularly those sorts of food noted for their strengthening properties, contain nitrogen in large proportions; and so inseparable is the presence of nitrogen from the nourishing qualities of food of all descriptions, that the value of feeding materials depends in a great measure on the quantity of nitrogen they contain.

It must be borne in mind that the oxygen and nitrogen of the air are merely mixed together and not chemically combined.

It is important to understand in a clear manner the distinction between a mechanical mixture and a chemical combination. In a mechanical mixture, each constituent remains unaltered in its essential characters, and may generally be recognized in the mixture by the naked eye or by a microscope, and in most cases may be removed from the mixture by mechanical means; and further, when separated, will be found in the same condition as it was before being added to the mixture. The appearance and external properties of a mixture are regulated by those of its constituents. On the contrary, in a chemical combination, or, as it is called, a compound, one substance at least is essentially altered, and by no amount of examination by the naked eye or a microscope can the constituent particles be detected. Hence the smallest particle is of the same quality as the bulk of the substance, the whole being perfectly uniform and homogeneous. Moreover, the qualities of compounds are not regulated by those of their constituents. Liquids may produce solids; gases may produce liquids; poisons may be formed from innoxious substances: so no opinion can be formed of the characters of a compound by judging of the qualities of its constituents.

Two or three examples will render this more intelligible. When chalk is powdered and mixed with water a creamy liquid results, possessing qualities intermediate between those of chalk and water. On standing, the chalk settles to the bottom, and the clear water is the same as before the experiment. If instead of chalk we use plaster-of-Paris the creamy liquid in this case will quickly harden and finally become a solid mass ; the water will disappear, and no longer be perceptible by the properties it exhibits in a liquid form. In this latter case the materials employed have combined together chemically. Again, gunpowder is a mechanical mixture, although a most intimate one ; it consists of charcoal, brimstone and saltpetre. By washing in water the nitre is dissolved, and now can easily be removed and separated from the two other ingredients by filtering and straining. The nitre may be obtained in a solid form by evaporating or boiling away the clear liquid over a lamp or fire until it dries up. The other two constituents—sulphur and charcoal—may also be separated by suitable means, which need not be described here. Each constituent thus separated from gunpowder will be found in precisely the same condition, as regards its chemical characters, as before being manufactured. But, as we all know, if fire is applied to gunpowder, it is instantly consumed, leaving nothing but a small residue ; in other words, its constituents have combined chemically—and how different are the resulting compounds ! Except a trace of solid matter, nothing but smoke is seen, yet these products, with some invisible gases, contain all the sulphur, charcoal, and nitre that existed in the gunpowder. These materials have assumed new forms, in which none of their original properties can be recognized.

Another remarkable property of chemical compounds may be briefly noticed, viz., they always contain definite proportions of their constituents ; from whatever source derived, they are invariably of the same composition and possess the same chemical characters. For instance, the compound known as chalk, or calcium carbonate, is found to be the same material, whether obtained from chalk rocks or prepared by passing carbon dioxide (carbonic acid) into lime-water. In both cases the chalk is chemically identical, and consists of 44 parts of carbonic acid gas and 56 parts of lime.

It has been wisely ordered that the oxygen and nitrogen of the air shall only be mechanically mixed, and not chemically combined. Had it been ordered otherwise, or were they suddenly to combine, the entire face of nature would be altered; the bland, health-giving air would be changed into the corrosive nitric acid, or aqua fortis. The only essential difference between the air we breathe and aqua fortis is, that in the air the above gases are mixed, and in the latter case combined, the proportions, however, being different. Marvellous as it may seem to persons unacquainted with chemistry, it is nevertheless true that air and the corrosive nitric acid are formed of the same materials. In making these remarks it would be more correct to say anhydrous nitric acid or nitric anhydride, which on combining with water forms nitric acid, the latter containing hydrogen in addition to the two elements previously mentioned.

We mention nitric acid, or aqua fortis, not only as a substance that might be formed from the constituents of the atmosphere but as one that is formed and in minute quantities is actually found in the air; while nitric acid in a concentrated form is a corrosive, destructive liquid, in a very diluted or in a modified form it is a valuable material for promoting the growth of plants. We often apply nitric acid to our crops when we use sodium nitrate (nitrate of soda), the well-known artificial manure, as a top-dressing. In this manure the nitric acid exists in a subdued, disguised form, none of its corrosive properties being displayed. In an analogous form, nitric acid is present in minute quantities in the rain that falls during thunderstorms.

It has been found that when currents of electricity are passed for a length of time through a portion of air, small quantities of nitric acid are formed, produced by the constituents of the air combining chemically together. This operation takes place on a large scale in nature, the powerful currents of electricity generated in the atmosphere, giving rise to the phenomena of lightning and thunder, induce the materials of the air to combine together, and nitric acid is formed. This substance again combines with another body called ammonia, also present in the air, and both together form a salt, which is called ammonium nitrate. In this state it is conveyed to the earth and to the growing plants by the rain. Thus we see that the fresh, vigorous appearance of our crops often noticed after thunderstorms is due to a small dose of valuable manure they have received, in addition to the ordinary refreshing effect of the rain.

Although the quantity of combined nitrogen present in the atmosphere at any given time is of course very small, yet the amount of this element washed down by rain in a year is considerable. At Rothamsted the following results have been obtained as a mean of five years: as ammonia, 2.4 lbs. per acre; as nitrates and nitrites, 1 lb.; as organic nitrogen, 1 lb., making a total of nearly 4½ lbs. of nitrogen per acre. It will of course be easily understood how greatly the circumstances of a particular time and place would influence the proportions, much larger quantities having been found by some other investigators in different situations. The proportion of ammonia in the air appears not to exceed ·01 grain in a cubic foot. It is also found that rain-water contains in every million parts from one to two parts of ammonia; when care is taken to obtain it as pure as possible smaller quantities are found. The bulk of the nitrogen supplied from the atmosphere by rain is brought down in the summer months, when but little drainage, generally speaking, occurs, hence it is nearly all obtainable by the roots of plants.

Properties of Carbonic Acid Gas (Carbon Dioxide).

The next constituent of the atmosphere that demands our attention is carbonic acid gas. Excepting nitric acid, we have described only the materials of the air provided for the accommodation of animals; let us now consider carbonic acid, and the material especially provided for administering to the wants of plants.

Carbonic acid gas forms a comparatively small proportion of the atmosphere—about one part in every 2,000 parts of air by weight, or, roughly speaking, three volumes in every 10,000 of air. Small as this quantity seems in relation to the vast bulk of the atmosphere, the absolute quantity of carbonic acid gas is really immense, and sufficient for supplying the entire vegetable world with the chief material for its growth. Carbon dioxide contributes to the health of plants in a manner analogous to that exerted by oxygen towards animals. We shall better understand the enormous quantity required when we remember how large a portion of the dry matter of crops, trees, and plants of all kinds consists of carbon, the presence of which is rendered evident by the blackening produced upon burning materials of this character; in fact, carbonic acid is the source from which plants derive the greater part of their substance—they feed upon it, and appropriate it as animals do food.

In a free state, carbonic acid gas possesses the following properties: it is an invisible gas, having a slight odour, and is considerably heavier than the air; it is a decided poison to animals; like nitrogen, it instantly extinguishes all burning bodies. Carbonic acid gas not only forms a part of the atmosphere, but in a solid state exists in rocks, minerals and soils to a great extent. In chalk, marble, and other calcareous rocks, it forms nearly one-half of their weight; in most rocks of this description about 44 lbs. of every 100 lbs. consist of carbonic acid gas.

Both the gases we have hitherto described are simple or elementary gases. Carbonic acid differs from them in being a compound gas—one that can be separated into two other materials. Carbonic anhydride consists of oxygen chemically combined with the solid substance carbon, or charcoal. In every 44 lbs. of this gas there are 12 lbs. of charcoal and 32 lbs. of oxygen.

Carbonic acid gas is thus always found when oxygen combines with carbon or charcoal; and as this carbon is the prevailing constituent of all materials used for fuel, it is clear that wherever fires are burning in grates or furnaces enormous quantities of carbonic acid escape into the air. Carbon also forms a large proportion of the food of animals; and by their breathing, this carbon is partly converted into carbonic acid gas. Before proceeding any further, it will be well to make ourselves acquainted with the properties of carbon.

Properties of Carbon.

Carbonic acid gas, as we have seen, consists of oxygen gas chemically combined with the solid substance carbon, or charcoal. In forming this combination, the carbon and oxygen put aside the characters they possess in a separate state and together become a new substance, possessing new properties totally distinct from those of either of its constituents. One of the constituents of carbonic acid gas—oxygen—has already been described; let us now direct our attention to carbon. As above-mentioned, 44 lbs. of carbonic acid gas contain 12 lbs. of carbon, or charcoal—we say charcoal because this substance is the nearest approach to pure carbon. Coke, soot, coal, etc., are all varieties of carbon, of different degrees of purity. We are all familiar with the black, porous, brittle, solid charcoal, the form which carbon usually assumes when in a separate or uncombined state; it is however known in another and more attractive form; viz., as the precious diamond. It is a fact tolerably well known, yet none the less marvellous, that the diamond is chemically identical with charcoal. Both consist of carbon ; the only difference being that the diamond is perfectly pure carbon in a crystallized state, while charcoal is carbon said to be "amorphous", or devoid of peculiar shape. Thus we see how much the arrangement of the particles of a substance determines its external properties and appearance. Carbon, with its particles loosely arranged, with spaces or pores between them, represents black, brittle, common charcoal ; the same material in a compact, dense form constitutes the transparent, hard, glittering gem, diamond. Numerous examples of this kind might be noticed. Gold and silver, for instance, when finely divided, are greyish-brown powders, altogether devoid of the metallic lustre peculiar to these metals.

Carbon is a most abundant material of the globe, especially in the animal and vegetable kingdoms. In the bodies of animals, carbon forms a large proportion of their weight, and in vegetables a still larger proportion ; about half the weight of dry wheat, hay, roots, etc., consists of carbon. Carbon occurs to a less extent in the mineral portion of the earth. In coal, graphite (the mineral of which the so-called blacklead pencils are made), limestones, chalk, marble, etc., a large proportion of carbon is present.

When wood or vegetable products are burned, their carbon and other combustible substances they contain, are consumed ; that is, the carbon combines with the oxygen of the air and passes off as carbonic acid gas. If, however, the combustion is arrested before all the inflammable matter is burned away, the greater part of the carbon is obtained in the form of charcoal.

Charcoal, or carbon, in the black brittle condition usually met with, is distinguished from its insoluble and imperishable qualities. A piece of charcoal buried in the earth will remain there any length of time without showing symptoms of decay. Advantage is often taken of this property of charcoal to preserve from decay timber that is buried in the earth, as gate-posts, posts of fences, etc. By charring the surface of wood, a layer of carbon is formed, which in a great measure preserves the inclosed wood from further destruction. Another remarkable property of charcoal is its extreme porosity. On examining a piece of charcoal by a magnifying-glass, it will be found to be full of minute pores or tubes; these fine tubes absorb gases, in the same manner as a sponge does fluids. In this way charcoal is capable of absorbing and fixing large quantities of certain gases. Its power of absorbing ammonia gas is particularly large. In a dry condition, charcoal absorbs 90 to 100 times its own volume of this gas. To a less extent, but still in considerable quantities, charcoal absorbs poisonous and disagreeably-smelling gases. It is noteworthy that gases evolved during putrefaction, such as ammonia and sulphuretted hydrogen, are especially capable of absorption by this material. Hence charcoal is a valuable disinfectant; it absorbs and retains noxious vapours floating in the air, from infectious and other sources, and may be used with much benefit as a means of purifying hospitals and other places where poisonous organic or contagious matters are likely to be present.

Charcoal is also capable of absorbing and removing the small quantities of putrefying animal or vegetable matters that sometimes render water unfit for domestic purposes. When, however, we have any doubt about the safety of our water-supply it is important to at once take measures to find out the real state of the case, and in the meanwhile first boil and afterwards filter, preferably through a clean charcoal block, all we require for drinking purposes. Indeed, so active is charcoal in removing offensive and unwholesome smells and effluvia of every description, that a layer of it placed on the putrefying carcasses of animals or other offensive things, effectually prevents the escape of any unpleasant odour or poisonous emanations. When required to exercise its absorptive properties charcoal should be freshly prepared. If found to have lost its power in this respect we may restore it by heating to redness out of contact with the air.

The above statements will aid us in understanding a process continually going on in our cultivated soils, and affecting in some measure their fertility.

All soils, particularly garden moulds, contain *humus.* This substance is formed from the vegetable matter left in the soil from previous crops ; it resembles charcoal in many of its properties (amongst others is its colour, the dark colour of cultivated soils being due to the humus they contain), and may be regarded as charcoal resulting from the process of decay. Hence it is called sometimes humus-coal. The two substances differ in this respect. That while ordinary charcoal is almost imperishable in the soil, humus, on the contrary, undergoes a gradual destruction, the oxygen of the air uniting with it and furnishing a supply of carbonic acid gas, etc., for the use of plants. The two materials are, however, so far alike that humus also possesses, though in a less degree than charcoal, the property of absorbing gases, especially ammonia gas. In virtue of this property, the humus of the soil absorbs and retains ammonia from the atmosphere, in which it exists in minute quantities. The ammonia thus collected is supplied, through the medium of water, to the roots of plants, in whose organism it performs the important functions that will be described in a subsequent chapter.

The heat given off during the burning of wood, coal, and all kinds of vegetable materials, is the result of the intense chemical action between the combustible elements of the fuel (the chief of which is carbon) and the oxygen of the air. Without entering into an explanation of the nature and causes of heat, it may be taken for granted that whenever substances combine together chemically heat is produced. In the process of burning or combustion the combination between the combustible materials and the oxygen of the air takes place with great rapidity, and a corresponding amount of heat is liberated ; this gives rise to the phenomena of fire. Fire is nothing more than a rapid liberation of heat. When the combination takes place slowly, as in the process of decay, the same amount of heat is produced ; but as in this case the liberation extends over a length of time, no perceptible warmth is produced. In the process of respiration, or the breathing of animals, this combination between combustible materials and the oxygen of the air takes place in the lungs at a speed intermediate between that of combustion and decay. In this vital process the oxidation is so regulated that an amount of heat is produced sufficient to sustain the necessary warmth of the body. Thus the process of respiration is closely allied to the operations of combustion and decay. In each case heat is produced by the oxidation of combustible materials. Further, the materials concerned in either process are the same, as are also the ultimate products of this oxidation.

These combustible materials are conveyed to the bodies of animals in the food they eat. A large proportion of most feeding materials consists of substances of this kind, which may be regarded as fuel for sustaining the animal warmth. Oil and fat, sugar and the starch of flour, are examples of this sort of food. As we shall learn in a future chapter, these facts are intimately associated with the theory of feeding and fattening cattle.

The greater part of the carbon consumed in the food of man and animals is thrown off as carbonic acid gas in the breath exhaled. It is for this reason that animals require fresh air, and die if deprived of it, or when confined in a space where the vitiated air cannot escape. If we remain in a small room, where the carbonic acid gas of our breath cannot escape, it is clear we must in a short time breathe it over again ; and since this gas is, as before mentioned, a poison, its inhalation must be attended with inconvenience and disturbance of health. The small proportion of carbon dioxide present in the air is not felt, because we are accustomed to receive it ; but any quantity larger than this normal quantity always produces effects more or less serious. Even the comparatively small quantity of carbonic acid gas which exists in the atmosphere of crowded rooms, theatres, etc., produces headaches, sleepiness, and other disagreeable symptoms ; but if the quantity is still larger, it produces serious derangement, and even death, as in suffocation by charcoal or coke fumes—an accident of not unfrequent occurrence, and one that is generally caused by persons ignorant of the simplest chemical laws. These fumes contain not only carbonic acid but also small quantities of a far more poisonous gas called carbonic oxide, another compound of carbon and oxygen, the proportion of the latter element being half that present in the carbonic acid gas.

Hence we learn how necessary it is that the rooms we inhabit should be properly ventilated, or at least provided with some means of ingress and egress for the air.

That carbonic acid gas is really formed in the process of breathing, and is present in the breath we exhale, can be shown by the following simple and interesting experiment. Whenever carbonic acid meets with lime it forms a white substance called calcium carbonate (carbonate of lime), or, in familiar language, chalk. This fact furnishes us with a test for lime, or the means of recognizing its presence. To apply this test for carbonic acid we use lime dissolved in water—lime-water, as it is called. It is made by adding to some water, in a jug or bottle, caustic, or freshly-burned lime. The muddy liquid is left at rest until the lime has settled to the bottom and the liquid becomes perfectly clear. The clear liquid contains lime in solution. By blowing through a small glass tube or the stem of a tobacco-pipe, into a little of this lime-water contained in a wine-glass, the clear liquid becomes milky, owing to the formation of fine particles of chalk produced by the carbonic acid gas of the breath combining with the lime of the lime-water.

The identity of the carbonic acid of our breath and the carbonic acid emanating from a burning candle or fire can be demonstrated by the following experiment :—A piece of candle, or, better, a wax taper, is attached to a wire, and the wire suspended from the cork of a wide-mouthed bottle (a pickle-bottle will do extremely well for the purpose). If we now light the candle or taper, place it in the bottle, and put in the cork, the taper will burn a few minutes, and afterwards go out, for it will have produced so much carbon dioxide as to prevent a continuance of combustion. On pouring into the bottle a little lime-water and shaking it, a white milky substance will be observed, as in the first experiment. Further, by the same test, we may prove that marble, chalk, or limestone of any sort contains carbonic acid gas in a fixed or solid form.

Some fragments of chalk or limestone are placed in a small bottle with a little water and a small quantity of oil of vitriol, or spirits of salts of the shops, is added. A boiling up, or effervescence, will ensue, caused by the escape of carbonic acid gas. This gas may be examined in the following manner :—A distinguishing property of carbonic acid is its great weight compared with the air ; consequently, it will flow from one vessel to the other like a fluid. By placing the bottle containing the acid and chalk in an inclined position, with its mouth near to that of another empty bottle (the bottle used in the preceding experiment will do very well, if washed out two or three times, taking care to fill it with water each time), the carbonic acid gas in the first bottle will flow into the second, and may now be tested by adding lime-water ; as before, a white milky substance will be formed.

It will be noticed that the quantity of carbonic acid in the atmosphere is constantly augmented by the combustion of fuel, the breathing of animals, and the process of decay, putrefaction, etc. When we recollect the thousands of tons of coals consumed in this country alone, the multitude of animals on the globe, the millions of human beings, all pouring carbonic acid into the air, we are amazed at the prodigious quantities of this gas that must be added to the air. How is it that this gas does not accumulate to an injurious extent? What becomes of all this poisonous gas? These are questions that naturally occur to us on becoming acquainted with the above facts. Before seeking replies to these questions it is well to recollect that the oxygen of the air diminishes in proportion as the carbonic acid accumulates. To be more precise, every 44 lbs. of carbonic acid removes 32 lbs. of available oxygen from the atmosphere. Hence we must not only find out in what manner the pernicious carbonic acid is removed, but also by what means the indispensable oxygen is replaced. Both these operations are performed by plants. Plants breathe the carbonic acid gas rejected by animals, and appropriate a part of it; plants *inhale* carbonic acid; by a wonderful organization they decompose it, separate it into its original constituents—carbon or charcoal and oxygen gas. The former substance is retained as a material for adding to their growth and building up their stems, leaves, and fruit, while the oxygen is *exhaled*, and returns to the atmosphere. Thus plants return to the air the oxygen borrowed from it by animals. At the same time animals prepare food for plants by reconverting the rejected oxygen into carbonic acid gas, which to them is a wholesome and necessary food. Thus plants and animals not only promote each other's welfare, but are actually dependent on one another for existence. In the light of these facts we cannot but see how important an effect the growth of trees and plants must have upon our atmosphere, and the reckless removal of the former without any attempt at replacement most certainly deserves condemnation, not only on this account, but also because they have great influence in promoting rain.

THE MOISTURE OR WATER OF THE ATMOSPHERE.

Let us now consider the fourth constituent of the air, viz., watery vapour, or water in the shape of invisible gas. On boiling, water passes into steam, which disappears in the air. This is because the air is capable of dissolving or taking up water in this gaseous or vaporous form. When water is exposed to the air in an open vessel it gradually diminishes, and, if left long enough, entirely dries up and disappears ; in this case it also passes into the air. Everyone must have noticed that the evaporation of water proceeds more rapidly in warm weather than in winter. The reason of this is that warm air dissolves or takes up a great deal more water than cold. Hence we find the proportion of water in the atmosphere constantly varying, being greater in warm weather than in cold. Evaporation takes place from all natural waters exposed to the air. From the surface of the sea, lakes, rivers, etc., water constantly rises in invisible vapour or gas and mixes with the air. That apparently dry air—as that of a room in which we live—really contains a large quantity of water may be proved by exposing to air substances that have a great attraction for water—"hygroscopic substances" as they are termed. A substance of this sort is well known, and may be easily procured by the name of pearl-ash (crude potassium carbonate). If a small quantity of pearl-ash is exposed to the air it gets moist, and finally runs to a liquid. This change in its condition is merely induced by the water attracted from the air. If we take the trouble to weigh the substance at the time of exposure, and again after a little time, an increase of weight will be found ; this additional weight is water absorbed from the air.

We cannot sufficiently appreciate the benefit we derive from this water dissolved in the air. By it the air is softened and moistened, so that the delicate organizations of plants and animals to which the air gains access are not injured or irritated as they would be were the air dry and totally devoid of moisture. We must all have felt the unpleasant and even injurious effects of air deficient in moisture in the bleak, cutting east winds that in this country so commonly mar the beauty of our spring months.

It is probably in the form of rain and dew that the water of the air most deserves our admiration. These beautiful phenomena, that contribute so much to our welfare and happiness by the essential service they render in the growth of all our crops, are formed by the steam or vapour of water in the atmosphere returning to its original liquid condition.

Ammonia.

Another constituent of the atmosphere remains to be noticed, viz., ammonia, which, although it forms but a very small proportion of the air, yet contributes in no small degree to the benefical effect of the air upon plants.

In speaking of nitrogen it was mentioned how reluctantly and by what indirect means only this gas combined with other gases and substances. As if to compensate for this inactive and indifferent disposition of nitrogen in a free state, its compounds are remarkable for the essential service they render in promoting the growth of plants and contributing to the nourishment of animals. Ammonia is one of these compounds of nitrogen, and forms a most useful and universal means of providing this necessary, perhaps the most necessary, material requisite for the growth of plants. It exists in minute quantities in the atmosphere, as before stated (page 41), and also forms an important part of most natural and artificial manures.

Ammonia consists of nitrogen and hydrogen (another gas that will presently be described under the head of

Water), chemically combined. It possesses properties so peculiar and so different from those of its constituents, that we are sometimes led to forget its origin and regard it as an elementary substance. Ammonia is well known by the name of hartshorn, a name probably derived from the ancient method of preparing it by burning horn or bones in a closed vessel. In a free state ammonia is a gas, invisible and colourless, but possessed of a powerful, irritating, pungent smell. Unmixed with air, this smell is so overpowering as to be injurious and destructive to life ; but, when much diluted with air, is said by many persons to be agreeable and refreshing. In this diluted state ammonia is frequently used for smelling-bottles. Whenever animal matters, as horns, hair, feathers, bones, etc., are burned, the nitrogen they contain combines with the hydrogen also present, and ammonia is formed, which passes off with the smoke and other strong-smelling compounds simultaneously formed, so that the ammonia cannot be recognised by its well-known smell, but may easily be detected by suitable tests.

A similar action takes place more slowly when animal matters decay or putrefy. Another source of ammonia is coal. In all coal a little nitrogen is present ; this in burning becomes ammonia. If the coal is burned in open fires the ammonia is lost, but when coal is heated in closed vessels, as in the process of gas-making, the ammonia is usually collected by suitable means. From this source nearly all the compounds of ammonia met with in commerce are obtained.

Ammonia in a pure state, or as usually present in the air combined with carbonic acid gas, is an extremely volatile substance ; it flies off as soon as produced, and by heating is driven out of any mixture containing it. The liquid known as spirit of hartshorn is ammonia dissolved in water. It possesses properties like potash, soda, or lime. Ammonia belongs a class of substances called alkalies ; and since this is a term often employed in describing chemical changes, it may as well be explained in this place. Soda, potash, and ammonia resemble each other in possessing a peculiar caustic or alkaline taste, hence they are called alkalies. They also produce when handled a slippery, soapy sensation on the fingers ; and, further, they all possess the power of removing or concealing the characteristic properties of another class of bodies called acids, or sour substances, as vinegar and sulphuric acid or oil of vitriol. Alkalies and acids are said to be antagonistic to each other, because, in combining together, they fight, so to speak, and deprive each other of their characteristic properties.

When we try to improve sour beer by adding to it soda we avail ourselves of these properties of acids and alkalies. We find the sour taste disappears ; at the same time the unpleasant taste of the soda is not perceived : the two substances have neutralised each other. The acid and the soda are still present, but all their characteristic properties are disguised.

The intensely sour acid called oil of vitriol may be neutralised in this way by soda or any other alkali. Whenever acids and alkalies thus neutralise each other a new substance is formed, with a taste neither acid nor alkaline, but saline ; hence the term salt. When soda is added to sour beer (it need scarcely be said beer becomes sour from the formation of vinegar) a salt is formed, which remains dissolved in the liquid. Ammonia is distinguished by being the only volatile alkali—the only one that flies off by exposure or heating. This may be proved by a simple experiment, which is very instructive, inasmuch as it enables us to understand what is meant by the expression " fixing ammonia", so often used by agricultural writers. A little spirits of hartshorn—that is, a solution of ammonia in water—is boiled in a small clean vessel over a lamp. The ammonia will rapidly escape into the air, and after a short time the liquid left in the cup will have lost its pungent smell ; all the ammonia will be volatilised. If we add vinegar to another portion of hartshorn until the pungent smell is overcome, and now boil this liquid as before, no ammonia will escape ; it is retained by the acid, and has now become a salt: it has been fixed. We may obtain this salt in a solid form by evaporating the liquid until it dries up. The white saline mass contains all the ammonia combined with the vinegar (ammonium acetate).

Ammonia in a free state is often liberated in stables or from recently-turned farmyard manure. In this condition it rapidly flies off and is wasted, unless measures be taken to prevent it. We shall run far greater risk of loss if we allow the litter to form too small a proportion of the mass. Excessive dryness will also cause additional loss, although exposure to rain should be avoided, for reasons to be found later in the book. The best way of avoiding loss of ammonia by volatilisation is to sprinkle the manure with diluted oil of vitriol, or in stables by adding sawdust to the dilute acid and exposing it in basins or other shallow vessels. The ammonia is thus converted into a salt (ammonium sulphate), and is fixed. Its escape may also be prevented by mixing superphosphate with the heaps.

In this fixed condition, or, more correctly speaking, in the form of salts, ammonia is generally met with ; for instance, the ammonia obtained from coal is usually converted into sulphate or muriate of ammonia. The ammonia contained in guano, soot, and other artificial manures is chiefly present in the form of salts, in which state it cannot be recognised by its peculiar odour. It may, however, be detected by the following test :—Any salt of ammonia, as ammonium sulphate (sulphate of ammonia) from the gasworks, or the dry salt left after adding vinegar to hartshorn in the above-named experiment, is mixed with a little slaked lime and moistened with water. Free ammonia is now rapidly evolved, and may readily be recognised by its powerful smell. The acid in the salt of ammonia leaves the ammonia and combines with the lime ; the ammonia is thus set free and resumes its volatile condition. Guano may be tested in this way for ammonia.

We have noticed that ammonia found in the air is mostly present in a volatile form. How, then, it may be asked, is it conveyed to plants, in whose development it plays so important a part? The following paragraphs explain the means whereby nitrogen in this and other forms is rendered of service to them :—

1. Plants possess the power of absorbing ammonia directly from the air by the leaves ; but the quantity most plants obtain in this manner is extremely small.

2. The nitric acid, formed as before mentioned, during thunderstorms, and probably in smaller quantities at other times by the currents of electricity which constantly pass through the air, on meeting with the alkaline substance ammonia, combines with it and forms a salt, called ammonium nitrate; this salt is actually found in rain-water and snow, particularly in rain falling during thunderstorms (page 41). In this manner plants obtain a small quantity of nitrogen.

3. In speaking of charcoal its property of absorbing gases was noticed. It acts towards gases in a manner analogous to that of a sponge towards fluids. Charcoal in a porous dry condition eagerly absorbs ammonia and retains it until moistened with water, when the ammonia it has absorbed is transferred to the water. On drying, the charcoal is again ready to absorb more ammonia. A substance closely analogous to charcoal is found in soils, called *humus*, which has already been described on page 46. This humus acts towards ammonia in a similar manner to the above, even in its natural moist condition. Other substances also present in the soil act in a similar manner, as clay, alumina, oxide of iron (ferric oxide), etc. These materials will be described in the next chapter. The ammonia thus collected, in common with that derived from other sources, and all nitrogenous substances, readily undergoes, when circumstances

are favourable, a certain change in the soil, to which fuller reference will be made on a future page.

4. The soil always contains organic substances, which upon oxidation yield their nitrogen in a form available to the roots of plants.

5. Certain plants, by means to be described presently, are able indirectly to make use of the free nitrogen of the air, a property of the highest value and importance, not in their own development only but also in preparing the soil for future generations of plants apparently not possessing the same ability, for the nitrogen yielded upon their decay is assimilable by all classes of vegetation.

The above are the means provided by Nature for supplying plants with nitrogen, and are amply sufficient for the requirements of plants in a wild state, where they have plenty of soil to grow in, the produce also remaining on the land. But with cultivated plants the case is different; these are often grown on poor, thin soils, that contain very little humus and very little clay; the nitrogen present in these soils is insufficient for their proper development.

This deficiency is supplied by adding to the soil manures. Nitrogen in some form is an essential constituent of farmyard manure, bone manure, guano, and most other manures. By this means cultivated plants are supplied with the quantity indispensable to their luxuriant growth.

From the nitrogen supplied from any of the above sources plants obtain the materials requisite for the fabrication of their seeds and other choice parts of the structure that afterwards become the food of man and animals.

Since the action of ammonia and other sources of nitrogen, in the shape of manure, is a matter of great importance in agricultural chemistry, we shall again refer to this subject in a future chapter.

The atmosphere is admirably adapted for the part it performs in the economy of nature. Thus in order that the exciting oxygen may not act too violently on the organs of animals, or combine too fiercely with combustible bodies, it is diluted with a bland indifferent gas—nitrogen. In this dilute condition oxygen is restrained from injurious activity, at the same time it is at liberty to perform those functions allotted to it for the proper maintenance of animal and vegetable life.

Again, carbonic acid gas is required. This, as we have seen, is a poison to animals, but a necessary food of plants. In order that plants may be supplied with this gas without its interfering with the health of animals, it is present in but a very small proportion, too small to act injuriously upon animals, yet large enough to supply all the wants of plants, the organism of which is so constructed that they are enabled to collect the small quantity of carbonic acid from a large bulk of air: this they do by the numerous leaves, which expose a very large breathing-surface to the air.

The heavy carbonic acid gas and lighter oxygen and nitrogen gases are intermingled and maintained in a nearly uniform state by a peculiar natural law, called the "law of diffusion of gases". This law may be described as a tendency all gases exhibit, when opportunity offers, to intermingle or diffuse themselves. Thus, a gas that possesses any peculiar smell, on being liberated in the air, does not remain in one spot, but rapidly diffuses and pervades the surrounding air, in virtue of this tendency. Again, a bottle or vessel filled with any one sort of gas cannot be retained in a pure or unmixed state if the vessel containing it is not perfectly closed; if there is the least opening communicating between the bottle and the external air, the air will begin to pass in and the gas begin to pour out, so that, after some little time, the gas will entirely escape from the bottle; and this operation takes place independently of the gas being heavier or lighter than the surrounding air. Were it not for this provision the heavy carbonic acid gas would settle to the bottom of the atmosphere in the portion nearest the earth; but, in consequence of this law, all the constituents of the atmosphere are equally distributed and preserved in a perfectly uniform condition. Portions of air have been collected from different parts of the earth's surface and from different heights; in all cases the composition is found to be the same, at least so far as the proportions of nitrogen and oxygen are concerned. In making this remark we are aware that the air of certain localities is occasionally impregnated with certain vapours and miasma injurious to human life; but these local defects in the air, that are often produced by our own carelessness and neglect of sanitary matters, must not be considered as affecting in any way the general composition of the atmosphere. The air as we generally find it, or as it is provided for us by God, has no other effect on our systems than that of increasing our health, strength, and happiness.

Thus, in the atmosphere we are able to perceive what we believe extends to all natural productions, viz., a perfect adaptation for the purposes they are provided to fulfil.

CHAPTER III.

THE SOIL.

Origin of Soils.

The greater part of the surface of the land is covered by a layer of loose earthy matter, consisting of a mixture of stones of different sizes, sand, clay, and other mineral substances, with varying quantities of decaying vegetable and other remains. This mixture is found to vary most widely in different localities, and constitutes what we call the soil. It is often but a thin layer, occurring in patches on the ragged surface of hard rocks, and capable of supporting nothing in the shape of vegetation but a scanty crop of mosses, lichens, and plants of this description. In other places it consists of a deep mass of vegetable mould, so fertile and productive that the simplest cultivation is sufficient to raise from it the finest crops of grain and every sort of food for man and animals. In many instances deposits of this sort are so rich and of such apparently inexhaustible fertility, that year after year they produce the most abundant crops without receiving anything in compensation in the shape of manure. Between these extremes in the qualities of soils every description of soil is met with, differing as much in colour, texture, depth, and all other external characters as in their capabilities of affording nourishment to plants.

It may be stated as a general rule that all soils are produced from rocks by some or all of the numerous destructive operations to which these are exposed. This destruction, or breaking up of rocks, is effected by several stupendous operations constantly going on in nature; for instance, volcanic action, floods, ice, and snow are described by geologists as active agents in changing the forms of rocks. The most effective agent, however, in altering their original condition and changing the character of the earth's surface, is the atmosphere, including the phenomena of rain, frost, etc., which act chiefly mechanically; as well as the chemical effects exerted by the oxygen gas, carbonic acid gas, and other constituents of the air already noticed.

Whenever the surfaces of rocks are exposed to the action of the weather they undergo a slow but sure process of decay—they rot, or disintegrate, as this process is termed by geologists. Fragments, more or less bulky, are constantly detached by frost, or some of the means before mentioned; these separate into smaller pieces, and finally crumble to powder. We have noticed, when speaking of the constituents of the air, the extraordinary avidity with which the oxygen gas unites with certain bodies that are in a condition to receive it. Bodies of this sort frequently occur in rocks and minerals ; and supposing them to exist at the surface, or within the reach of oxygen gas, combination will ensue ; and the resulting compound being always more bulky, or otherwise different from the original form, a disturbance of the surrounding parts takes place, accompanied by a loosening of the surface of the rock. Again, the carbonic acid of the air has a great tendency to unite with several mineral substances of constant occurrence in rocks. For instance, there is a mineral called felspar present in many rocks. Where this mineral is exposed to the carbonic acid of the air it is slowly decomposed and separates into two new substances, which are useful in contributing to the growth of plants. These two substances are called respectively potash and silica. We shall again have occasion to speak of these substances at greater length in another division of this chapter. We mention them here merely because the mineral felspar is a good illustration of a substance belonging to rocks that quickly become altered when exposed to the atmosphere. The mechanical effect of rain and frost must also be noticed in considering the various means that assist in the breaking up or crumbling of rocks and minerals. It is well known that frost is most active in this respect, at least in countries like our own, where intermittent frosts are common in winter. It owes this activity to the fact that water in the act of freezing expands with irresistible force ; hence, if water is contained in any receptacle unable to yield to the increase of bulk consequent on its freezing, the vessel is certainly broken ; this is the case with the strongest iron vessels. In the fissures and interstices of rocks water often accumulates, collected from the rain, dew, and other sources. This water will, on the occurrence of a frost strong enough to penetrate to these places, be frozen, and the brittle rock, unable to contain the water in its enlarged condition, is split and torn apart; on the ice thawing, or, in other words, the water again becoming fluid, these detached fragments are loosened or fall away. By this means alone enormous masses of rock are separated from the faces of cliffs, which in many places get visibly less and less every winter. The rain also materially assists the above-mentioned agents in their united attacks on the surfaces of rocks and minerals: it not only washes away the finer particles of detached material, and thus exposes fresh surfaces for the renewed action of oxygen gas, carbon dioxide, etc., but in many instances dissolves the rock itself; and although the quantity of substance removed in this way is small, yet in the course of time appreciable diminution in bulk may be seen to have taken place from this cause.

From the above general facts we may form some notion of the manner in which the surface of an exposed rock, supposing it to be tolerably level, or at most undulating, may be gradually converted into a soil. We can easily imagine how, by the unceasing action of the oxygen and carbonic acid gas of the air, combined with the occasional effect of frost, rain, etc., fragments are loosened and detached, then crumble down and accumulate, until a layer of sufficient thickness is formed to retain enough water to preserve it in a porous, moist condition. Mosses and plants of a low organisation will now spring up, then in time will decay, and furnish to the imperfect soil a quantity of decaying vegetable matter; it will now be in a condition to allow of the growth of a higher class of plants, whose seeds may accidentally be conveyed to the spot. Vegetation being once established, the vegetable matter—the humus of whose properties we have already made mention, and concerning which we shall have more to say later on—will steadily increase, until a due proportion is present to constitute a soil. This soil will, of course, be strictly dependent on the characters of the rock from which it is formed; all its qualities—its colour, texture, etc.—will resemble those of its parent rock. If this rock contain all the mineral constituents requisite for the vigorous growth of plants, the soil will be a fertile one ; if, on the contrary, the rock is deficient in any of these constituents, a soil of corresponding quality results. And this is the distinguishing character of soils of this class, viz., that they always partake of the qualities of the rock on which they lie, and consist for the most part of fragments of this rock in different stages of pulverisation.

Another class of soils must now be noticed, whose origin is somewhat different from the above, and whose characteristic property is that they do not always partake of the characters of the rock on which they rest. Thus far we have only spoken of soils that have been directly produced on the surface of rocks by the breaking up of these surfaces when exposed to the action of the weather. This operation can only take place when these surfaces are tolerably level, or at the utmost undulating, and never on the sides of rocks that are at all steep or precipitous. Before inquiring into the character of this second class of soils, let us briefly account for the occurrence and describe the formation of the vast masses of gravel, sand, clay, etc., which form so large a portion of the surface of the land, and on which the greater number of soils rest.

Whenever the sides of rocks are steep and precipitous, or occur in the shape of cliffs, their destruction in the manner above described is considerably hastened ; the fragments separated by any of the before-mentioned means fall away as soon as detached and accumulate at the foot of the cliffs or in the valleys of the mountainous district. The rain also washes away the finer particles, and carries them down to the lower grounds, when, perhaps, streams or rivers convey those substances still further away. Again, if districts like the above are exposed to floods, great quantities of loosened material are carried away and transported to considerable distances ; during which operation these rough fragments undergo more or less alteration in form, and assume the rounded shape commonly possessed by the pebbles found in gravel. While this loose matter is thus drifted along the valleys of the district in which it is formed it will probably get mixed with the remains of other rocks of a different kind, brought down by similar means from neighbouring valleys, and thus will be deposited masses of material derived from several sources, in situations far away from the original position occupied by the particles of rock that composed them. These masses of drifted materials, altered by grinding against one another, by the action of water and other forces, make up the bulk of what we call clay, sand, gravel, etc. ; they may all be described as mixtures of powdered rock, more or less altered by geological agents.

The surfaces of beds of this description are converted into soils by means similar to those we have already spoken of as acting upon rocks. The operation in these cases is, of course, quicker, and the resulting soil generally of a better kind than soils formed on the surface of hard rocks, since, in accumulations made up of fragments of several kinds of rocks, a greater number of the mineral constituents required by plants are likely to be present than in any one rock. Other circumstances being equal, it may be assumed that a soil of this sort is superior to one of the former class.

Another matter connected with the formation of soils must now be briefly considered, viz., the occurrence of different kinds of soil in close proximity to one another. We often notice, in districts of limited extent, several distinct kinds of soil indicated by their colour, texture, appearance of the crops growing upon them, etc. ; and if we are at all acquainted with these soils, we generally find them as different in quality as their appearance would lead us to suppose. A variety in the character of the soil is often noticed in a comparatively small space of ground. More than one kind of soil is commonly found on a farm ; even in one field it is not rare to find two or three descriptions of soil.

This difference in the character of soils is, as we have seen, in a great measure dependent on the underlying rock, or the deposit on which the soil rests ; hence we may generally assume that a difference in soil is accompanied by a corresponding difference in the subjacent rock or deposit ; so that to account for the absence of uniformity in the soils of a district we must seek for an explanation in the laws which regulate the position and arrangement of the rocks, beds of clay, gravel, and all other materials of the earth's crust.

Whatever kind of material may exist at the immediate surface of the earth, there is always found at a depth, varying in different localities, a solid rock. Of course the rocks found in this way vary to an immense extent in quality, character, appearance, and in every respect ; but, however different they may be, we are able to class them as belonging to one or the other of the two great divisions into which all rocks are divided. In cliffs, quarries, railway-cuttings, and other situations where the interior of rocks is laid bare, and we have an opportunity of examining their structure, we may notice that most rocks are deposited in regular beds, layers, or slices, called by geologists strata. In one and the same face of rock we may often see two or three different layers, composed of rocks widely different from each other in colour, texture, and every external quality. Rocks that are deposited in this manner, in layers or strata, are called stratified or sedimentary rocks. The number of stratified rocks is very great ; but of their numbers, characters, qualities, or origin, we shall not speak, merely taking for granted their existence.

These stratified rocks are arranged in nature in a series one above another, in regular order. This series forms the upper or outer portion of the crust of our globe. In this series each bed of rock has its appointed place, and is generally found in this place—at least in regard to the other rocks found above or below it.

It must also be mentioned that the accumulations spoken of by the names of beds of clay, sand, gravel, etc., have also been deposited in layers or beds, generally at the top of the stratified rocks. Hence we often find cavities and irregularities in the surfaces of rocks filled up and overlaid by materials of this sort.

At the bottom of this series of stratified rocks are found the unstratified rocks; that is to say, rocks that have not been deposited in this regular manner, but which are uniform throughout their bulk; from the lowest parts of them we can reach to their highest summits. We say these rocks occur at the bottom of the stratified rock, but they also occur in all other positions with regard to the series of stratified rocks, protruding through them, displacing them, overlaying them, and rising far above them. Another name for these rocks, that will throw some light on the above statements, may now be noticed. They are also called eruptive rocks. The class being sub-divided into two groups, often distinguished as plutonic and volcanic, the former, for the most part, never having been raised above the surface of the earth, the reverse being the case with the latter, for not only have they reached the surface, but may even have been poured out as lava. These rocks are all the result of volcanic action. By the stupendous effects of volcanoes and other mighty agents, that at one time or another have extended to most parts of the earth's surface, these volcanic or unstratified rocks have taken up the extraordinary positions above mentioned, and in so doing have displaced the stratified rocks from their original level position, and compelled them to assume a broken form at all sorts of angles with the level surface of the earth. Thus we find the series of stratified rocks, or parts of the series, inclined in all directions, often the edges of the beds uppermost. By this violent treatment, the layers of rocks have been somewhat deprived of their regular order, many of the beds having been removed in one place and heaped up in another, creating all sorts of apparent confusion.

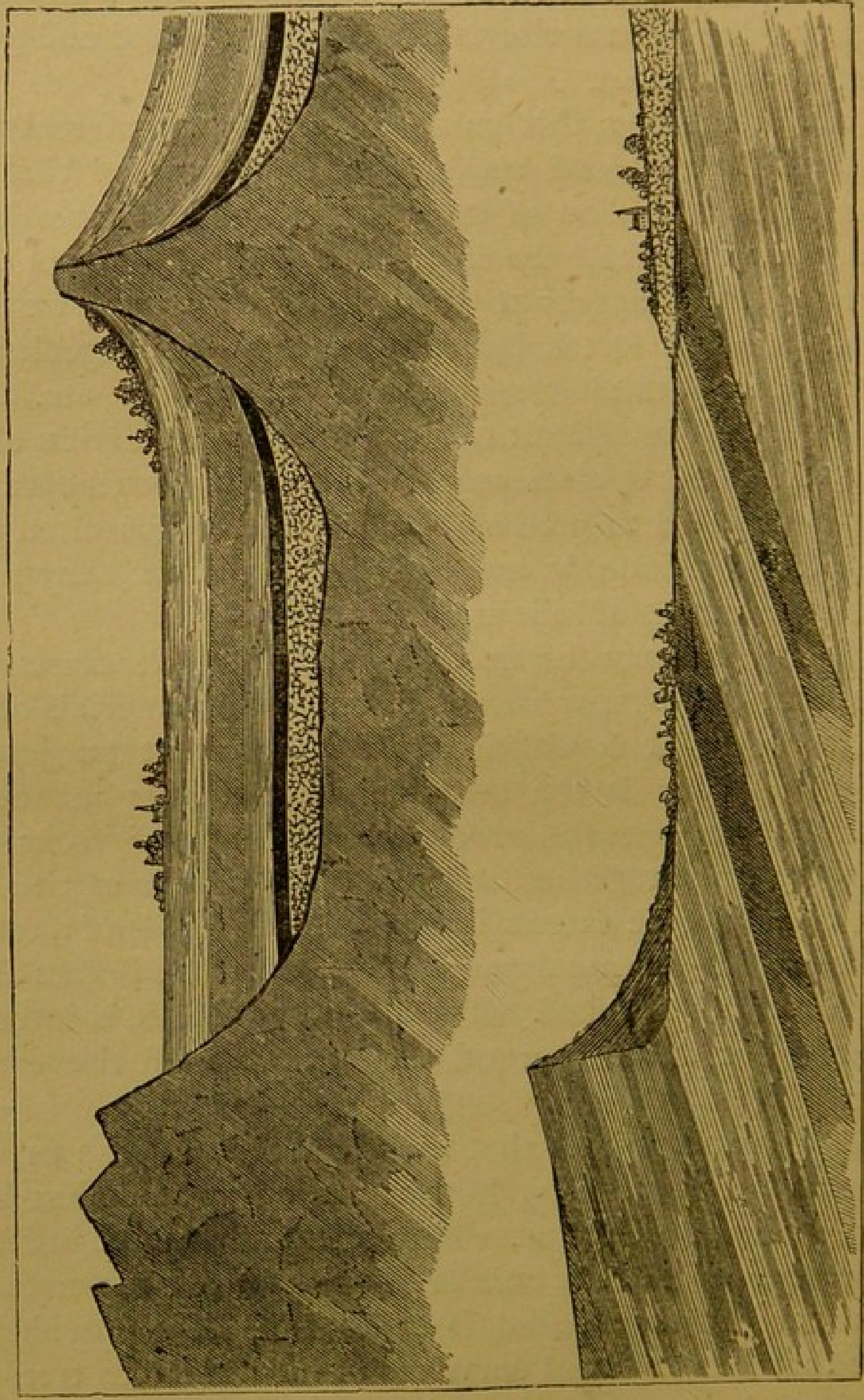
To these effects of volcanic action must be added those of water, in the shape of floods, torrents, and inundations, which, by washing down and intermixing the materials of the rocks, have given rise to the deposits of sand and gravel as before mentioned.

Notwithstanding this complete mixing up of rocks, the order of the stratified rocks is so far preserved that the presence and position of any one rock or bed beneath the surface may generally be inferred by the position of some other rocks that appear at the surface, or to which we have access. On this fact is based the application of geology to the purposes of mining, agriculture, well-sinking, etc.

Of course, it is difficult to form an adequate notion of the vastness of these operations, or of the stupendous means that must have acted to produce them. These beds often form entire tracts of country, and the edges of inclined strata are sometimes ranges of hills and mountains.

It is unnecessary for us to inquire into the causes that have led to this apparent confusion in the materials of the earth's crust. It is sufficient for our present purpose to know that such is the fact, and that in this manner is explained the occurrence of several kinds of rocks and deposits nearly together at the surface of the earth ; and thus, also, to some extent, is explained how soils of a totally different character are found close together, and often alternating in the same field. The following sketch is intended to convey some notion of the structure of the earth's crust.

We may also remark that the above facts furnish us with an opportunity of seeing how much our welfare has been regarded by the Creator. This seeming want of order in the arrangement of the beds or layers in which the materials of the earth are deposited, is evidently kindly provided, in order that we may avail ourselves of the numerous treasures contained in some of these beds. Were it not for this apparent confusion, all but the layers exposed at the surface of the earth would be utterly inaccessible to us, and we should for ever remain in ignorance, and suffer from the



want of the numerous useful things occurring at greater depths which we at present enjoy.

We will now consider the soil more in detail, and first describe the various substances that are found therein, their properties, uses, and their connection with agriculture.

Organic Portion of Soils.

The soils of our gardens and fields, widely differing in many respects, are so far alike as usually to present a brown or black colour, inclining more or less to red. This dark colour, found more especially in garden mould, and to a less extent in all cultivated soils, is mostly due to *humus*.

In all soils are found vegetable remains in different stages of decay. Some of these so far retain their original form as to be easily recognized as parts of roots, stems, leaves, and other parts of plants. There is also a black, friable substance, consisting of the above-named vegetable substances, more completely decayed, so that no organized shape can be perceived. This constitutes the substance in question, viz., humus.

Not long ago it was believed that the fertility of a soil is in direct proportion to the amount of humus it contains. Such, however, is not the case. It is now known that this, although a most useful constituent of the soil, does not alone regulate fertility.

That the fertility of a soil does not depend on the amount of humus it contains is clear, when we recollect that peaty soils, naturally of inferior quality, contain more of this substance than any other descriptions of soils. Again, many soils famous for the heavy crops of wheat, and other crops they produce, contain but a small proportion. It is nevertheless quite true that with an insufficient supply of this material a soil is sure to be poor in nitrogen, whereas a soil in which an abundance of humus is present always has a good store of that important element. By laying land down with grasses and clovers we favour the collection of humus, and consequently of nitrogen. This explains the advantage known to be gained by so treating our land before sowing cereals.

In addition to the properties mentioned on p. 56, humus is found to have a greater capacity for containing water than either sand or clay. This fact is especially noticeable when it contains much half-decomposed vegetable remains, as roots, stems, leaves, etc., hence soils rich in it are less liable to suffer from drought, and the addition to excessively porous soils of materials capable of forming this substance will be followed by beneficial results, for not only is a moister condition ensured, but the particles of soil are more closely bound together, hence we have one reason for the value of green manuring. The dark colour imparted to land in which humus abounds renders it capable of absorbing more heat from the rays of the sun than soils of a lighter colour, a property possessed by all dark-coloured bodies. This fact has of course an influence of great value under certain circumstances.

This constituent is also useful in the soil as a source of carbonic acid gas—another of the materials already described as necessary for the growth of plants. The quantity of this compound made use of through the roots would seem to be small, for plants are considered to obtain by far the greater part of their carbon from the atmosphere. The carbon dioxide derived from the slow decay of organic matter is of much value, however, in increasing the solvent power of the water of the soil. By slowly decaying, humus of course furnishes a constant supply of this gas.

Thus we see humus plays an important part in supplying food to plants. It is, however, occasionally found in a condition different from that we have just described; and, so far from performing the important functions we have mentioned, it refuses to decay, and seems to be an encumbrance to vegetation. In this form it exists in boggy and peaty soils, and is popularly, though erroneously, called "sour humus". From this torpid inactive state humus may generally be aroused by drainage and the use of lime, as we shall notice on a future occasion.

Besides humus, other substances of vegetable and animal origin are also present in the soil, as the undecayed stems, roots, and other parts of plants, and the larvæ of insects; these materials are all comprised in the term "organic matter", applied to them by chemists.

Before leaving our consideration of the organic portion of the soil it seems desirable for us to describe the process of nitrification, upon which so much light has been thrown in recent years by the admirable researches of Mr. Warington and others. Much of the information given on this subject has been abstracted from the writings of the former. Plants appear capable of making use of nitrogen in the form of compounds of nitric acid and ammonia, but that present in the soil as organic matter they seem, generally speaking, unable to assimilate, at least to any great extent. For this to become available a remarkable change must be undergone, the nitrogen passing first into ammonia, and finally into nitric acid, which combines with some substance such as calcium carbonate, from which it displaces the carbonic acid to form a nitrate, which, as we have seen, is a class of compounds plants are well able to deal with. But the most astonishing feature of the process is, that this production of nitric acid, concerning which something has been said in the section of this book devoted to the atmosphere, is brought about by the action of minute living organisms. That nitric acid, which, as one of the earliest known and strongest, might almost be taken as the type of a mineral acid, should owe its origin to an organism is a very remarkable fact, and one calculated to invert some of our ideas as to the chemical constitution of matter. Mr. Warington's latest researches appear to indicate that nitrification is the result of the work of two such organisms, one of which produces *nitrous acid*—a compound of nitrogen and oxygen, in which a smaller proportion of the latter element is present than in *nitric acid*—while the other acts upon the nitrous acid salts to form nitrates, which we shall recognise as the substances formed by the combination of nitric acid and an alkali or other material capable of uniting with it. There can be little or no doubt that the first organism has been separated and well inspected, while the evidence of the isolation of the second is also very strong. Both would seem to be members of one family, for, although their functions are quite distinct, it having so far been found impossible to make one perform the other's task, the resemblance between them with regard to appearance is very striking. For nitrification to proceed satisfactorily, moisture, a sufficient supply of air, a warm temperature, and some substance called a base, with which the acid formed can combine, are necessary. Hence we can understand that greater activity will prevail in the hotter months of the year; in fact, the process is said to be stopped by frost, although this latter sometimes serves a good purpose, the land in severe weather being preserved from loss by drainage through its instrumentality; for when ground is in a frozen state it is impossible that any water should pass, and even upon any covering of snow thawing, the greater part will merely run off the surface before the soil is softened; therefore any material loss in this direction is guarded against.

This ready conversion of nitrogenous organic matter and ammonium salts into nitrates is a matter which has an enormous influence upon agriculture, and unless the farmer is watchful it may, instead of being a great advantage, become a means of serious loss; for these salts are very soluble and readily carried away in drainage water, so that when we bear in mind the following facts and the too often wet character of our seasons, we shall see the force of the above remarks. It has been estimated that the total amount of nitrates produced on land at Rothamsted lying without a crop for fifteen months equals about 80 lbs. of nitrogen per acre. Now evidently the proportion left for the benefit of future crops must be largely dependent upon the weather, and should much rain fall the loss of valuable plant-food will be great indeed. The best way to avoid such loss is clearly to grow some green crop on the land, and either plough it in or return its constituents by some other of the several well-known methods to the soil; this course has the advantages of retaining the nitrogen in an insoluble form, which upon decay is yielded in a readily available shape, of accumulating it and other valuable constituents in the surface soil, while at the same time a supply of useful food for stock may be provided.

A point of great interest and importance is to be found in the explanation of this fact, that by continually growing such a crop as wheat upon land we bring about a gradual decrease in the proportion of nitrogen in the soil, excluding the consideration of that removed as produce, the reason being that cereals commence active growth in spring, which growth concludes when they bloom. The nitrates of the soil often to a great extent drain away in the autumn and winter, and the rapid formation of a fresh supply has not long been in progress when it ceases to become available for those crops, on account of the stage they have reached in their growth. Hence there is a tendency towards loss of the nitrogen oxidized during the formation and ripening of the grain, which will of course be greatest during a rainy season. We readily see that a crop which grows throughout the summer, when the production of nitrates is most abundant, is not open to the same objection. By a judicious system of cropping, etc., we shall be able to use our knowledge of the facts now mentioned to the greatest advantage.

If a portion of dry soil is burned in an iron spoon, or other more convenient receptacle, over a lamp or fire, the soil first blackens, sometimes smokes, gives off the peculiar smell of burning earth, and generally assumes finally a red colour. These changes are principally due to the destruction by fire of the organic matter present in the soil, the distinguishing property of all organic compounds being that they are destroyed or separated into their constituents by burning. The greater portion of the soil remains behind, and is generally a little darker coloured or redder than before burning, but otherwise unchanged by the action of heat. This is the

Mineral or Inorganic Portion of the Soil.

This portion of the soil forms in most cases by far the greater part of its bulk and weight. It consists of a mixture of mineral substances, all of which take a more or less active part in assisting the growth of vegetation. While some of them act only mechanically by giving bulk and porosity to the soil, the greater number, in addition to this effect, act also chemically, that is to say, directly contribute to the growth of plants by supplying them with indispensable materials. The number of mineral constituents usually found in soils is eleven or twelve, and what may at first seem astonishing is the fact that this number seldom varies in fertile and unfertile soils. In soils of almost every kind this number of components is present. The proportion of these materials determines in a great measure the quality of the soil. The fertility of land, however, is likewise affected by the condition in which these materials occur; for instance, the compound called phosphoric acid, before referred to as a substance intimately connected with the fertility of soils, is very seldom absent in any case; but although a soil may contain considerable quantities of phosphoric acid, the direct supply of this fertilizing agent is often marked by beneficial effects. Paradoxical as the fact may seem, it is easily explained, as follows:—The phosphoric acid naturally present in the soil may exist in one of its stony, insoluble shapes before alluded to: in this form it is incapable of entering into the delicate vessels of the roots of plants, and remains ineffective, whilst the supply of the same substance in a condition in which it can be taken up by plants produces most desirable results. Hence also the necessity of employing proper means for rendering available the useful materials already present in a soil.

The names of the inorganic or mineral substances belonging to the soil are : Silicon, Aluminium, Calcium, Iron, Magnesium, Potassium, Sodium, Sulphur, Phosphorus, Chlorine, Fluorine. In this list we have arranged these materials in the order of their abundance, as they occur in a soil of average fertility. We will now proceed to describe the more prominent characters of each of these substances.

SILICA is the predominating constituent of most soils, rocks, and minerals. It forms a large proportion of clay, and the chief part of sand ; in short, silica is the most abundant solid material of the earth. In a pure state, silica is a white gritty powder, which is scarcely affected by any ordinary chemical agent, and remains unaltered when exposed to the strongest fires. It consists of silicium or silicon, and oxygen. These negative properties extend to nearly all the ordinary compounds of silica called silicates ; there is, however, one remarkable exception in the case of soluble silica, as it is called—a combination of silica that is soluble in water. This compound is found in all fertile soils, and its influence upon the growth of plants will be touched upon later. In a great many plants, as wheat, barley, and others of this description, we find a considerable quantity of silica, which has been conveyed into their structure as soluble silicates by the agency of water. We are familiar with several combinations of silica in the different varieties of glass commonly met with. Bottle-glass, window-glass, etc., are all composed of silica and various bases forming silicates, with smaller quantities of other materials. Silica is also called silicic acid, and occasionally silex. The compounds of silica are of little value in the soil until they are disintegrated and broken down by the prolonged action of frost, water, etc. Water holding calcium carbonate in solution is found to be especially useful in bringing about their decomposition.

ALUMINA.—Alumina combined with silica forms pure clay. The white clay of which pipes are made is nearly pure clay. The clays found in soils have usually a red colour, due to the oxide of iron they contain. They consist of pure clay intimately mixed with fine sand, oxide of iron, and some other substances. Clay in a moist state is a smooth, plastic material, retains water with great obstinacy, and on drying retains the shape given to it when moist. Alumina in a dry state much resembles silica : it is a white, gritty, solid, exceedingly hard substance, which is sometimes found in nature in a crystallised state. The gems ruby and sapphire consist of crystallised alumina. Alumina consists of oxygen gas and the metal aluminium. It will be recollected that this metal when first produced in comparatively large quantities attracted much attention and curiosity under the name of the new metal made from clay, although it was a mistaken idea to suppose it was newly discovered, for it had been known to chemists for some years. Like the metal calcium, contained in lime, or sodium in soda, aluminium before that time could only be procured in small quantities. The only thing new about this metal was the discovery of a more ready method of separating it from its combinations, and obtaining it in larger quantities, so as to admit of its qualities being better observed. By means of an improved process, which has quite recently been still further improved, aluminium is now obtained at moderate cost, and is made into spoons, forks, etc. It is a metal whose appearance is intermediate between that of silver and zinc, its most remarkable quality being its extreme lightness. A bar of the metal lifted up conveys the impression of lifting only a rod of wood. It would no doubt be more used for domestic purposes, but for its unattractive appearance, and difficulty of working.

Persons unaccustomed to remark chemical phenomena may well be astonished on being told that a bright silvery metal is contained in the clay of our fields ; yet such is the case.

And now, while speaking of aluminium and the other metals of the soil, let us make a few additional remarks on the substance with which they are nearly all found combined. This substance is oxygen gas, the same gas we have described as the vital constituent of the atmosphere. Is it not extraordinary that this element, displaying so many active properties when in the state of gas in our atmosphere, should also exist in a solid form in earth and minerals under a totally different aspect, as remarkable for its passive and inactive qualities as it is for the reverse of these qualities when it occurs in the air? Oxygen furnishes us with a good example of a body that assumes more than one condition, and also of the fact that one substance may present several different shapes when combined with different bodies. Thus we have already seen it forms the greater part of silica or sand, also of alumina and clay ; and we shall find it forming the chief portion of all the materials of the soil. To return to our subject, let us inquire into the connection of alumina with agriculture.

Alumina does not directly contribute to the growth of plants—it is seldom absorbed by their roots, and, therefore, is no direct food to them. In the form of clay, however, it is a most essential constituent of the soil.

Clay, as above noticed, is very retentive of water ; hence, in hot, dry weather the clay of a soil becomes of great service in protecting the plants grown upon it from the injurious effects of drought. At times, when the surface of the soil is apparently parched for want of water, if a little of the upper dry earth is removed, the subjacent soil will generally be found moist enough to prevent crops of most kinds growing in it suffering for want of water. This property of soils is due to the humus and clay they contain.

Another important use of clay in soils depends on its power of combining with and retaining the easily soluble salts supplied in manure and from other sources. Were it not for this property of clay, these fertilizing substances would be washed down by the first heavy rain into the subsoil, and be taken out of the reach of the roots of plants. By this provision, however, they are retained in the clay, and supplied to them when required. This property of clay enables us to understand the expression often applied by farmers to soils deficient in clay, such as sandy and light soils, which are said to be "hungry". Another important property of clay is its power of absorbing the valuable ammonia from the atmosphere, thus rendering it more available to vegetation.

Oxide of Iron (Ferric Oxide).—This substance is closely connected with the two preceding ones, being generally found with them in greater or less abundance in clays, sands, and other minerals. It is oxide of iron that gives rise to the prevailing red and brown tints of these substances. The blue colour sometimes noticed in rocks and clays is also due to oxide of iron of another sort. Blue clays on exposure to the weather speedily change their colour, and finally become red. This circumstance is explained by ferrous oxide, to which the blue colour is due, rapidly attracting oxygen from the air, whereby it is converted into the red or ferric oxide.

When a piece of bright iron is exposed to damp air, it quickly becomes covered with oxide, and, if exposed long enough, is entirely changed into rust. The red-coloured friable substance formed in this way is oxide of iron, or the same substance which is found so abundantly in soils, sands, rocks, etc. In a moist state, as it is found in the clay of soils, oxide of iron, like alumina, possesses the power of absorbing and retaining ammonia, potash, and phosphoric acid. Although the combinations with the two first do not appear very stable, those formed with a class of compounds called hydrous silicates are found to be far more so with these and other bases, while that possessed by oxide of iron for phosphoric acid is very strong.

The other oxide of iron, above referred to under the name of ferrous oxide, has usually a blue tint, and occurs in the well-known salt of the shops called green vitriol or copperas. This substance is occasionally found in soils, and exerts an injurious effect on vegetation, although some modern experiments would appear to lend support to the view that under certain circumstances this salt, whose correct name is ferrous sulphate, possesses some value as manure. It is also hoped that in the event of further investigations into the effect of cupric sulphate and lime upon the potato disease proving favourable, a substitute for the first substance may be found in the less expensive iron compound. It is occasionally formed in soils from a mineral of not unfrequent occurrence, called iron pyrites, or iron combined with sulphur. This substance may often be seen forming yellow metallic scales in the cracks of lumps of coal. When iron pyrites is exposed to the weather under certain conditions, it is converted into sulphate of iron, or green vitriol, which, if present in more than a very small quantity, impairs the fertility of the soil. The barrenness of certain spots of ground has often been traced to the presence of ferrous sulphate (sulphate of iron) in injurious quantities; it occurs also occasionally in boggy and undrained land. By prolonged exposure to the air and weather, sulphate of iron loses its injurious properties by being changed into the red or harmless oxide of iron; hence, the obvious remedy for land injured by the presence of this substance is thorough working and fallowing. The same end may be more effectually attained by a liberal addition of lime to the land.

Iron in the shape of oxide of iron is very widely spread over the earth's surface, being present in small quantities in nearly all rocks and soils, and is occasionally found in them in so large a proportion as to admit of their being profitably employed as sources of metallic iron.

LIME.—Lime, in the chemical sense of the term, means the hot caustic substance recently removed from the lime-kiln, where it has been prepared by means of fire from limestone rocks, which for the most part consist of calcium carbonate (carbonate of lime); that is, lime combined with carbonic acid—the gas, it will be remembered, which forms a small proportion of the atmosphere. On burning these rocks, the carbonic acid contained in them flies off into the air, and lime, in the proper sense of the word, mixed with any foreign matter the rock may contain, remains in the kiln. In this state it is commonly called quicklime, caustic lime, or hot lime; it consists of oxygen gas, combined with the metal named calcium. In this freshly-burned state, lime is strongly caustic or alkaline; that is to say, it possesses a peculiar acrid taste, and, when moistened, produces a soapy sensation on the fingers. This effect is due to its corrosive action of destroying animal and vegetable matter. For this reason it furnishes us with a valuable means of improving land suffering from an excessive quantity of vegetable matter, found in peaty and boggy districts. On this, with other equally important properties, is based the use of lime as a means of improving defective soils; and since this operation of liming is an important one in agricultural chemistry, we shall speak of it at greater length in a future chapter, amongst other allied operations.

When a lump of quicklime is sprinkled with water it steams, cracks, gives off much heat, swells up, and finally falls to an exceedingly fine, white, *dry* powder; all the water used in the operation disappears. The lime is now said to be slaked, and retains its former alkaline qualities. The proper name of this slaked lime is calcium hydrate; the water used in slaking has entered into chemical combination with the lime, and with it has formed a new substance, in which none of the ordinary properties of water can be recognized. The heat given off during the process of slaking is the result of the violent chemical action. It is said the sudden slaking of large quantities of quicklime is a common cause of fire. Without entering into the laws that regulate the production of heat, we may state, as a general fact, that a liberation of heat, or, more strictly, a disturbance of temperature, accompanies every chemical action.

The slaking of lime is caused by the great attraction possessed by lime for water ; or, as chemists say, the affinity of lime for water is strong. The above changes are represented as following the rapid slaking of lime by pouring water upon it. It must be understood that the same thing takes place whenever the quicklime meets with water, as when exposed to the air and allowed to slake spontaneously. In so doing it derives the requisite amount of water from the atmosphere, which, as we have seen, always contains considerable quantities of its vapour.

Besides the affinity for water, lime has a great attraction for carbonic acid gas. Slaked lime exposed to the air, especially when moist, rapidly absorbs carbonic acid (hence the use of lime in removing carbonic acid from places where it has accumulated to an injurious extent), and is converted into carbonate of lime ; in fact, it returns to its original condition, and, chemically speaking, is in the same state as it was before burning. But its physical form is very different : it is now in a fine state of division.

We avail ourselves of this property of lime when applying it to land. As it would be next to useless to add to a soil calcium carbonate in the shape of lumps of limestone rock, we should secure the fullest benefit by adding and perfectly distributing the same material, prepared from caustic lime in the manner just described, simply because in this finely divided state it can be intimately mixed with the soil and at once come in contact with the substances on which it is intended to act. We may remark by the way, that the importance of attending to the state of division of a material intended to be added to the land extends to manures of all descriptions.

Lime is indispensable to the growth of plants; in many plants it is an abundant constituent of their ash, or mineral portion, and is found in greater or less quantity in almost all plants. Thus we see lime is a very important material of soils. No soil—or, rather, no cultivated soil—is absolutely destitute of lime, although the proportion of it in many is often less than is required for a healthy growth of plants; for it furnishes a base which we have seen is so important in the process of nitrification and other operations proceeding in the soil. Without a proper amount the latter is hindered in the exercise of its powers of retaining plant-food, a property with which the fertility of our land is without doubt intimately connected; lime also renders heavy soils more porous and accessible to the beneficial influences of the atmosphere, rain, etc., while to sandy ones it imparts firmness and cohesion; and consequently the addition of lime in many cases is calculated, for some of these reasons, to lead to an increase of produce. In the shape of carbonate of lime, by far the greater part of the enormous quantity of lime occurring in the earth's crust is found.

Lime also occurs, but less abundantly, in other states of combination; for instance, as calcium sulphate (sulphate of lime), calcium phosphate (phosphate of lime), calcium silicate (silicate of lime), calcium nitrate (nitrate of lime), etc. Two of these we must briefly describe. Sulphate of lime is also called gypsum, and is better known by its common name of plaster-of-Paris. It is found in tolerable quantity in many localities, often beautifully crystallized, and is widely distributed in most soils, but in very small amounts. It is found in the ash of many plants, especially clover, beans, etc.

Calcium sulphate, as its name would imply, consists of lime combined with sulphuric acid, or oil of vitriol, and generally contains a definite quantity of water chemically combined with it. On burning, this water is driven out, and the resulting burned sulphate of lime is plaster-of-Paris.

Calcium sulphate is of value as a manure to certain crops, but when superphosphate is employed, a special application of this substance can be of little service; for in placing five tons of superphosphate on our land, we at the same time apply two tons of calcium sulphate; gypsum—just mentioned as another name for this salt—is also found useful in preventing the volatilization of ammonium carbonate from manure-heaps, etc., a double decomposition taking place, or what may perhaps be described as an exchange of partners between the two salts, calcium carbonate and ammonium sulphate being formed. The same action would seem to be of value in retaining any ammonium carbonate present in the soil, a matter of most importance, probably, when from any cause nitrification is impeded.

Calcium phosphate occurs in soils in minute quantities: it exists in certain rocks, and occasionally entire beds of it are found. The minerals called apatite, phosphorite, etc., consist chiefly of this compound: hence these materials are valuable sources of calcium phosphate (phosphate of lime), for the preparation of superphosphates and manures of this description. As this compound of lime will also be considered amongst the manures, nothing further need be said of it in this place.

MAGNESIA.—This substance resembles lime in many of its properties, and is generally found accompanying it in rocks and minerals. Several kinds of rocks contain a large proportion of magnesia; as dolomite, some limestones, serpentine, etc. Magnesia, like lime, mostly occurs as carbonate, or combined with carbonic acid. It is also common as silicate, or combined with silicic acid. A variety of this combination of magnesia is well known as meerschaum, the material of pipe-bowls. Two other forms of magnesia are familiar to most of us, viz., ordinary magnesia alba of the shops, which is a mixture of magnesium hydrate and car-

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bonate, artificially prepared, and Epsom-salts, consisting of magnesia combined with oil of vitriol, or sulphuric acid (magnesium sulphate).

Magnesia is present in all cultivated soils, and is very necessary to the healthy growth of many plants. In wheat, barley, and plants of this kind, magnesia is always found, combined with phosphoric acid, especially in the shells or bran of the grain. Its presence in the soil seems to be necessary to the proper development of the seeds of these plants. Magnesium phosphate is found in company with phosphate of lime in the bones of animals.

POTASH.—When wood is burned, a greyish-white ash is left: this ash consists for the most part of potash, or more correctly potassium carbonate (carbonate of potash).

The ash left on burning wood and other parts of plants in all cases consists of the mineral substances taken up by the plant during its growth. The presence of this mineral matter in plants is not accidental; it is the mineral food of the plant, and as necessary to its growth as the other kinds of food we have before noticed—as ammonia, carbonic acid, etc. This subject being a very important one in Agricultural Chemistry, will be considered in a future chapter, and therefore need not be entered upon in this place. We allude to it because the potash in most cases forms a large proportion of the mineral constituents of plants and trees, and consequently is found in greatest abundance in their ash. For this reason potash is a most essential material in all cultivated soils. The principal source of potash is the mineral felspar. This mineral, as we have before noticed, occurs in many rocks; and hence is found in soils. From this mineral potash is slowly liberated by the action of carbonic acid and other agents, which render it available for plants, by whose roots it is absorbed.

On burning the vegetable portion of wood, the potash, amongst other mineral substances contained in it, is left behind in the shape of carbonate of potash. From this source nearly all the various compounds of the potash of commerce are obtained. In countries where wood is of little value, as in Canada, Russia, and other places, it is burned in immense quantities for the sake of the ash. This ash, by a simple process, is converted into the pearlash of the shops. Potash is now largely supplied from mineral sources, as noticed under Muriate of Potash (potassium chloride), and Kainite.

In some parts of this country the wood ashes are collected and extracted with water. This extract is technically called "lye", and is used to "soften" the water used in washing linen. It owes its virtue to the carbonate of potash it contains. The carbonate of potash in this lye, and from other sources, has a peculiar caustic taste and soapy feel; it is "alkaline", like the liquid ammonia and lime before described. Substances possessed of this quality are called alkalies and alkaline earths, potash being one of the first, while lime is a good example of the second. A distinction between them is the much superior solubility of the *alkalies* in water. When a solution of potassium carbonate—or, what is the same thing, the lye above noticed—is boiled with caustic lime, and the mixture allowed to stand until the upper portion is clear, a solution of caustic potash is obtained. This solution, when strong, is a very corrosive liquid, capable of dissolving skin, hair, and all animal matters. The soapy feeling experienced on the fingers when handling alkaline substances, as potash, soda, and in a less degree soap, is due to a thin surface of skin being dissolved and removed by these alkalies. Caustic potash consists of the metal potassium combined with oxygen and hydrogen gases. Potassium is a bright silvery metal, so light that it swims upon water, and in so doing takes fire. One of the prettiest chemical experiments consists in displaying this property of potassium. The violet colour of the flame produced is characteristic of this metal.

Potassium is a most interesting substance apart from its connection with agriculture, inasmuch as it was the first of the light metals discovered at the beginning of the present century by the distinguished chemist, Sir Humphrey Davy. Before this period, no one conceived that a bright metal was concealed in potash or in soda. These substances are formed from oxides of their respective metals—combinations of oxygen gas with potassium and sodium—which are considered strictly analogous to the rust or oxide of iron, which contains the metal iron and oxygen gas.

The use of wood ashes as a manure will be spoken of amongst the other manures in a future chapter.

SODA very much resembles potash. While potash is an abundant mineral substance of land plants, soda occupies the same position with regard to marine plants or seaweeds. These plants contain large quantities of soda ; it seems to perform in them functions similar to those performed by potash in land plants.

On burning seaweeds, sodium carbonate (carbonate of soda) is obtained : a salt closely analogous to carbonate of potash. This operation is carried on at different parts of our coasts, where seaweeds are collected for the purpose. The resulting ash is called "kelp"; it is largely consumed by the manufacturers of iodine, and was formerly used in soap-making, glass-making, and other trades. Kelp was at one time the only source from which carbonate of soda or washing soda, and caustic soda, were obtained, but at the present time these are made on an enormous scale from common salt. The proper name of common salt is sodium chloride, a familiar substance that furnishes us with a fine example of chemical transformation. Common salt consists of the metal sodium (a metal analogous to potassium) combined with a most poisonous gas called chlorine. Every 58 lbs. of common salt contains about 35 lbs. of this gas, which in a separate state possesses the following formidable characteristics: It is a heavy green-coloured gas, possessing, when mixed with the air, a peculiar suffocating smell; in an unmixed state it acts when breathed as a violent poison; indeed, this substance is always carefully handled by the chemist, and always prepared with much precaution. Yet this gas, of such ferocious qualities when uncombined, by union with sodium and some other metals becomes perfectly tame and passive, loses all its poisonous properties, and in the case of common salt becomes a most useful and beneficial addition to our food. Such is one of the many extraordinary facts presented to us on all sides by Chemistry.

It is in the shape of common salt that soda chiefly occurs in soils, and generally but in small quantity. Common salt is often found of much service for agricultural purposes, not only on the land, where any benefit resulting from its use would appear of somewhat obscure origin, although doubtless often none the less real and useful, but also for diluting sodium nitrate (nitrate of soda), and as a valuable constituent in the diet of our live stock. Experience on the Continent, in addition to experiments in our own country, support the view that good results do in many cases follow the application of this material to the soil, although most of our land would appear to possess naturally all that would be required by plants, for, with the exception of mangels, the quantity of its constituents made use of in our crops is very small, and would indeed appear non-essential. The possible value of a dressing of salt is, however, so largely governed by local circumstances, that any general statements must necessarily be made with considerable reserve. The occurrence of salt in soils, often found on rocks entirely destitute of it, is accounted for in the following manner. The rain is occasionally found to contain appreciable quantities of salt, derived from the sea; the spray and invisible particles of sea-water are often carried by high winds to great distances inland, where it is slowly deposited. The results of careful experiments, made with the view of determining the amount of salt conveyed to the land in this manner, distinctly show that the salt found in our soils is mainly derived from this source. The quantity is very variable, but reaches a large amount in the course of the year.

PHOSPHORUS.—All the materials we have described hitherto as belonging to, and forming part of, the soil, are combinations of metals with oxygen gas:—hence their proper name, metallic oxides. Two or three other substances of another type must now be noticed, which resemble the metallic oxides in so far that they are also combinations of oxygen, and are consequently oxides, but differ from them in possessing, when in a separate or free state, properties altogether different from and antagonistic to those we have hitherto considered. These, it will be remembered, always possess, when soluble in water, a peculiar caustic taste called "alkaline": hence they are called by chemists alkalies, and also bases. This latter term is applied to all compounds of the same character, whether alkaline or not. As we have said, the substances we are now about to consider are possessed of properties precisely the reverse of those belonging to bases. They are sour compounds, and called by chemists acids. Alkalies and acids are great antagonists, because, whenever they meet they fight, so to speak, and deprive each other of their distinguishing properties; they neutralise each other, and produce a new class of bodies called salts. We thought it proper to describe thus briefly the formation of a salt, to account for the circumstance that few acids or bases are ever found in a free state in nature: they nearly all occur in the form of salts. Moreover, a great part of the constituents of soils exists in the shape of salts.

Phosphorus when combined with oxygen forms several oxides, amongst which is one called phosphoric anhydride, the basis of phosphoric acid. Calcium phosphate, sodium phosphate, etc., are all salts of phosphoric acid.

In a combined form, phosphorus is contained in nearly all soils, but often in very minute quantities.

In the shape of phosphate of lime, phosphorus occurs in apatite, phosphorite, and the other minerals alluded to on a former page. The roots of plants take up phosphoric acid from the soil, and convey it to the different parts of their structure. Phosphorus is always found in the choicer parts of plants, as the grain of wheat, barley, etc.; in the bulbs of turnips, mangels, etc.; in fact, in all vegetable productions used as food for man and animals; and is always found in largest quantity in those portions of the plant remarkable for their nourishing properties. We thus see that phosphorus is intimately connected with the nutritive value of feeding materials.

From the combinations of phosphorus present in small quantities in their food, animals obtain the phosphoric acid essential to the development of their bones. The bones of animals contain a large proportion of phosphorus in the shape of calcium phosphate (phosphate of lime). Bones are the source from which the greater part of the phosphorus and compounds of phosphorus of commerce are obtained.

When bones are burned, they first blacken, and shrink in bulk; by longer burning, they are converted into a white ash. This ash is the mineral part of the bone: it consists chiefly of phosphate of lime. By suitable chemical means, the phosphoric acid can be separated from the lime, and from phosphoric acid phosphorus may be prepared. In a separate state, phosphorus is a yellowish semi-transparent solid, soft like wax, and possessed of a peculiar garlic-like smell. It is remarkable for being the most inflammable substance known, the least violence or friction being sufficient to set it on fire. On burning, it gives off clouds of white smoke. This smoke is anhydrous phosphoric acid.

The fact that a large amount of phosphorus is required by all crops, and that it is naturally present in the soil only in small quantity, readily explains the reason why the artificial addition of this substance is generally followed by an increase of produce. Phosphorus is conveyed to the soil by employing phosphatic manures, such as bone-dust, superphosphate of lime, etc.

SULPHUR.—The proper name of the substance commonly known as brimstone is sulphur. Combined with other bodies, sulphur is invariably present in the soils of our fields. Thence it is collected by the roots of plants, in whose organism it performs important functions, and, like phosphorus, is necessary to the development of those portions of plants which afterwards become the food of man and animals. Sulphur is found in large quantities, mixed with earthy impurities, in the neighbourhood of volcanoes, and by a simple procsss is purified and prepared in the form usually imported into this country. It is also found in considerable quantities in the mineral, iron pyrites.

When sulphur is burned, it combines with the oxygen of the air, and forms sulphurous acid gas, the unpleasant-smelling vapour generated on lighting lucifer-matches. This compound, by suitable means, can be converted into sulphuric acid, or oil of vitriol. The latter is now prepared on an enormous scale in vitriol works, vast quantities being consumed in this country annually, apart from the large amount exported.

Sulphur is an important article of commerce to this country, since, in the shape of oil of vitriol, it is indispensable in the carrying on of numerous trades and manufactures, and in an indirect manner is intimately connected with the processes of agriculture. Superphosphate of lime, a manure which may be regarded as a necessity in the present system of cultivation, is prepared by the direct agency of sulphuric acid. Very large quantities of it are annually consumed in this manufacture alone. Appreciable amounts of sulphur are brought down to the soil in the form of sulphates by rain.

CHLORINE AND FLUORINE.—Very little need be said of either of these substances, since chlorine has been before mentioned, and the latter substance—fluorine—is not of much interest in Agricultural Chemistry. Chlorine is chiefly met with in the form of common salt. In this form it exists in immense quantities in the water of the sea, but is only sparingly distributed in the soil. In a separate state, chlorine seems to take no part in the economy of nature.

Fluorine is very much like chlorine, and occurs in minute quantity in soils, combined with lime. It also occurs in considerable abundance associated with lime as the mineral fluor spar, and in smaller quantities occurs in many phosphatic minerals. It is taken up by plants, and conveyed to the bodies of animals, where its chief use seems to be in forming the enamel of teeth, and in smaller quantities is present in their bones.

Classification of Soils.

Of the substances previously mentioned, by far the more abundant in all soils are the four or five first in the list, viz., silica, alumina, oxide of iron, lime, and organic matter; next in quantity are magnesia, potash, and soda; finally, in very small quantities, phosphoric acid, sulphuric acid, and chlorine. These statements apply to all sorts of soils; whether a soil be light or heavy, calcareous or sandy, fertile or barren, its bulk is always made up by some of the five materials first named; the others always form but a small proportion of the soil, amounting together seldom to more than a hundredth part of its weight.

All the constituents described above may be grouped into four divisions, and considered as belonging to, and forming part of, one or more of the four natural materials, which, arranged in different proportions and distributed through various quantities of undecomposed fragments of rock or stones, make up the bulk of all soils. These four compounds are familiarly known to us as sand, clay, calcareous and organic or vegetable matter. An idea of the general composition of each of these four mechanical constituents, as they are sometimes called, may be gathered from the following table :—

Sand may contain—
- Silica,
- In small quantity. { Oxide of Iron, Lime.

Clay may contain—
- Silica,
- Alumina,
- Lime,
- In smaller quantity. { Potash, Soda, Phosphoric Acid, Sulphuric Acid.

Limestone or Calcareous Matter may contain—
- Lime,
- Carbonic Acid,
- In small quantity. { Silica, Alumina, Oxide of Iron, Potash, Soda, Phosphoric Acid, Sulphuric Acid.

Organic Matter, or Decaying Vegetable and Animal Matter, may contain—
- Humus,
- Other Vegetable Remains,
- Animal Remains,
- In small quantity, but in a fine state of division, and well incorporated (the mineral constituents of former generations of vegetables or crops). { Silica, Potash, Soda, Phosphoric Acid, Sulphuric Acid, Chlorine.

According to the preponderance of one or more of these compounds, soils are arranged in the following classes :—Vegetable moulds, clay soils, sandy soils, calcareous soils, marly soils, and loamy soils.

Let us now briefly consider the leading characters of each of these classes of soils.

VEGETABLE MOULDS.—All soils that contain a large quantity of vegetable matter, either in the shape of humus or otherwise, are included in this class. Here we find two distinct varieties of soils, viz., fertile moulds and peaty or boggy soils. By a large quantity of vegetable matter is meant more than 5 or 6 per cent.,* which is about the quantity usually found in ordinary soils. In garden moulds there is generally about 9 to 10 per cent. of organic matter ; in peaty and boggy soils, often as much as 70 per cent. Hence, although the relation between humus and nitrogen referred to on page 69 is true, the presence of a large amount of organic matter is not an infallible criterion of fertility.

* In stating the quality of soils, we generally speak of their composition in one-hundred parts, or say so much per cent. of a substance.

The superior quality of garden mould, as compared with the soils of our fields, is due not only to the organic matter it contains, but also to the surrounding circumstances being such that its constituents readily become available for plant-food ; the fine state of division and more complete mixture of its components are likewise matters of great importance.

In boggy and peaty lands it is this excess of vegetable matter, to which the air has but little access—oxidation consequently occurring on a very limited scale—that renders them unproductive, all the useful elements being in a locked-up condition. Hence the proper course towards their improvement consists in employing the most efficient means at our disposal for getting rid of or altering the condition of this vegetable matter ; in most cases draining, and afterwards the liberal use of lime, will effect this object. It is difficult to speak too strongly of the value of lime for such purposes. The new Thomas' phosphate will also be found of much service under these circumstances. In some instances burning is necessary; but as such a course involves a serious loss of nitrogen, it should not be undertaken without careful consideration.

Clay Soils.—Soils of this description are distinguished by their cold, dense qualities, and are well known as "heavy soils", for the reason that the successful cultivation of such land can only be accomplished by the expenditure of a great amount of labour, strength, and capital. We have already noticed, while speaking of alumina, the peculiar retentive quality of clay, and have remarked upon the usefulness of this property. But in soils that consist almost entirely of clay this quality becomes too much of a good thing, and constitutes the chief obstacle that the tiller of such soils has to encounter. For this reason little can be done with clay soils until they are thoroughly drained.

Another operation, sometimes resorted to in the reclamation of unproductive clay land, is burning, the burnt clay tending to increase the porosity of the soil; but for reasons just given this must be regarded as an extreme measure, and the same end is more satisfactorily gained by increasing the proportion of humus or by liming, which is also a valuable means of bringing into cultivation soils in which an excessive quantity of clay is the cause of infertility. The subsequent treatment in the management of clay soils consists in working them in as complete a manner and as often as the state of the ground will permit.

With a great amount of labour and expense clay soils become exceedingly fertile, and return a good profit to the cultivator, since they require less in the shape of manure than most other kinds of soil. This is because many clays contain inexhaustible quantities of the mineral substances required by plants, and only require proper management to yield those materials in an available form. Hence these soils are particularly adapted for the production of grain-crops, especially wheat. Clay possesses several advantages which many soils greatly lack: thus the loss of soluble salts by drainage is comparatively small, a season of drought having but little effect upon it; indeed, clay-land farmers say "drought never brought dearth to England". Of course this is a very strong statement; still, from their point of view, truth underlies it. This result is produced not only by the drainage being less, but also by the close texture of the material, which greatly increases the effect of a curious physical action known as capillary attraction, by whose means water present in the subsoil is conveyed to the surface, in company of course with any salts it may hold in solution, which, upon evaporation, it deposits within easy reach of the roots of plants; this will be recognised as a property of great value. Loams also possess it, but in sand very little of such an action takes place on account of the relatively large size of its particles. The large proportion of aluminium compounds in clay doubtless has a considerable bearing upon its ability to retain water.

Sandy Soils are those that contain from 70 to 90 per cent. of sand. They are distinguished by characters the reverse of those possessed by clay soils. They are light, porous, deficient in retaining moisture ; they soon suffer from drought, and by heavy rains are deprived of the little valuable matter they may originally contain. The chief defect of these soils is this want of retentiveness, which allows the rain and water to wash out the valuable portions of any manure that may have been supplied, before the roots of the plants have had time to take up these substances. Hence the term "hungry", applied by farmers to this sort of soil. For this reason, if at all practicable, the manure should be added in small and frequent doses. It is for the same reason that the system of liquid manuring succeeds on soils of this description.

The improvement of such soils obviously consists in adding clay, marl, etc., if such materials can be procured at a price at all consistent with the benefit they are likely to produce. It is also very desirable to increase the amount of organic matter in these soils, for, as we have seen, this constituent is best able to retain moisture.

Calcareous, or Lime Soils.—This is a most extensive class of soils, including many of most diversified characters. To this class belong all soils in which carbonate of lime forms the greater part of the bulk, or that contain more than 20 per cent. of lime; but since the rocks from which these soils are formed vary most widely in their composition and physical characters, it follows that soils of every degree of fertility are included in this division. Lime soils are generally light and easy to work ; the greater number are poor and thin ; some of them, however, as those resting on the lower chalk formation, are exceedingly good soils, and remarkable for their fertility.

Lime soils of all descriptions are particularly adapted for the growth of leguminous crops, as clover, pease, sainfoin, etc. This latter plant is particularly fitted for thin soils resting on limestone rocks, since it has the power of sending its roots to great distances in the fissures of the rock, and extracting and bringing to the surface the fertilizing materials it may contain.

Marly Soils are those that consist of a mixture of clay and lime, and contain from 5 to 20 per cent. of lime, and whose qualities are of course intermediate between clay and calcareous soils. These soils are subdivided into clay marls, chalk marls, sandy marls, etc. Marls of different kinds are often used as manures, and generally with good results. The effects produced by marls are usually more striking than those which follow the application of other calcareous matters. This superiority is mostly due to the phosphoric acid which many varieties contain.

Loamy Soils are intimate mixtures of sand, clay, lime, and organic matter. They are subdivided into clay loam, sandy loam, etc. These are probably the richest sorts of soils, next to the better sorts of vegetable moulds. Like the latter, they contain a fair proportion of clay, sand, lime, etc., thus combining the advantages of all these materials, and the whole in a friable well-mixed condition; and it is to this fact that the superior quality of loamy soils is mainly due.

In order to convey a better idea of the composition of soils, we annex the following analyses.

COMPOSITION OF SOILS.

	A Fertile Vegetable Mould	A Good Sandy Soil.	A Fertile Clay Soil.	A Fertile Loamy Soil.	A Calcareous or Lime Soil.
Organic Matter, etc.	10.08	.49	3.38	11 24	6.33
Oxide of Iron	6.30	3.19	8 82	4 87 }	9.31 (Oxide of Iron and Alumina)
Alumina	9.30	2.65	6.67	14.04 }	
Lime	1.01	.24	1.44	.83	30 55
Magnesia	.21	.70	.92	1.02	trace
Potash ... ... }	.10 (Potash and Soda)	.12	.48	.80 }	1.03 (Potash and Soda)
Soda ... ... }		.02	.08	.43 }	
Phosphoric Acid	.13	.07	.51	.24	trace
Sulphuric Acid	.17	trace	trace	.09	trace
Chlorine	—	trace	—	.25	—
Insoluble Silicates (clay and sand)	72.70	92.52	72.83	66.19	28.77
Carbonic Acid and loss ...	—	—	4.87	—	24 01
	100.00	100.00	100.00	100 00	100.00

	Fen Soil.	Heathy Sandy Soil.
*Organic Matter, etc.	52.63	2.50
Oxide of Iron and Alumina, ...	12.20	13.04
with Phosphoric Acid	.41	.07
Lime	4.81	.89
Magnesia	1.20	.70
Potash	.75	.73
Soda	traces	traces
Sulphuric Acid	traces	traces
S lica and insoluble silicates ...	26.60	82 14
Carbonic Ac:d, etc.	1.81	traces
	100.00	100 00
*Containing Nitrogen	1.70	.06
equal to Ammonia	2.06	.07

The examples of fen and heathy sandy soils recently examined by us may be taken as illustrating the extremes with regard to percentage of nitrogen ; the proportion present in the former must be regarded as exceptional, although soils of this description, together with garden moulds and the " maiden earth" of pastures, usually contain more than ordinary agricultural soils.

The fen soil also furnishes a remarkable instance of the accumulation of nitrogen in the soil, absorbed from the atmosphere and carried down by rain, which is appropriated by vegetation, the products of whose partial decay are constantly increasing in such cases, consequently a great part of this nitrogen exists in an inert form, and the soil would require treatment with caustic lime, etc., before it could be of much service to its cultivator.

In bygone years is was not customary to determine the nitrogen in soils, but we have here an instance which shows us how desirable and useful such information is ; we are also shown of what great practical value chemistry may be in indicating the wisest and most economical treatment.

On glancing at the foregoing analyses, perhaps the first thing to strike us is the very small quantities of the most valuable constituents present—thus the highest result shows only .41 and 2.06 of phosphoric acid and ammonia respectively ; but if we bear in mind the enormous weight of soil upon an acre of land, and then proceed to make a simple calculation, we shall be surprised to find how these apparently trifling quantities mount up. For example, we will take the weight of soil to be 700 tons, which is a decidedly low estimate, when the proportions of nitrogen and phosphoric acid referred to will equal about 56 tons of ammonium sulphate and 6¼ tons of tricalcic phosphate, the latter being as much as would be supplied by about 23 tons of superphosphate containing 27 per cent. of soluble phosphate. This is a result which will probably cause us to considerably modify our opinion concerning the importance of the figures in our tables.

The classification given is that usually adopted in the description of cultivated soils. The general composition of a soil, and its connection with one or other of the above classes, may in some measure be judged by examining it in the ordinary manner, by its colour, texture, the characters of the stones it may contain, the quantity of organic matter, etc. But to be able to speak positively on this subject it is necessary to ascertain the precise composition of the soil. This can only be done by a chemical analysis. It is the business of the analytical chemist to do this in such a manner that each constituent of the soil may be separated and its proportions determined. Even then a practical experiment is desirable before we can speak confidently as to their availability, for the chemist in his analysis employs more powerful means in separating the several elements of plant-food than plants themselves are able to command; hence much care and judgment are requisite in giving an opinion of a sample.

An approximate analysis of the kind first mentioned is not difficult to make, and might perhaps be performed by anyone so disposed; but since an analysis is of very little use unless the potash, phosphoric acid, nitrogen, and other more valuable parts of the soil are accurately determined, and as these operations require much care even in the hands of an experienced chemist, we do not think it desirable to describe in any way the processes for the chemical analysis employed.

We feel it advisable to say here that it is not necessary for all purposes to go to the expense of obtaining a complete analysis of a soil, for a partial one which can be made for a greatly reduced fee will often give a farmer the information he requires. Any fuller particulars concerning such analyses, in conducting which we are able to make use of the knowledge gained by long experience, we shall of course always be happy to supply.

Another kind of analysis, often of great service in judging of the capabilities of a soil, is called a mechanical analysis, and requires much less care and accuracy in its performance than a chemical analysis. This kind of analysis has for its object the determination of the relative amounts of organic matter, sand, clay, and lime, and in many cases is all that is necessary to decide important questions in the practical management of soils.

The value of chemical analysis in deciding agricultural questions is often very great, and in many cases at once determines whether a proposed scheme for improvement is calculated to succeed or not. For instance, in the important question of subsoiling, we can at once learn whether it is desirable or not to turn up the subsoil, by making a complete analysis of it; from the result of this analysis we can decide whether its admixture with the surface-soil is likely to produce improvement or injury. Subsoils often contain undesirable substances, which, if turned up, will of course exercise an injurious effect upon the surface-soil; on the other hand, valuable fertilizing materials often lie hidden in the subsoil, which might greatly enrich the surface.

Again, the infertility of a soil is often explained by an analysis. The soil may be suffering from the want of some material indispensable to the growth of plants, or it may contain something harmful to them; in either case chemistry is generally able to enlighten us, and to point out the means for remedying the evil.

Of a soil whose fertility is impaired, we can all pronounce that it wants manuring; but with the assistance of an analysis we may also learn in what substance the soil is deficient, or what kind of manure it wants. With this knowledge we may restore its fertility, in the most economical manner, by supplying those materials only that are required, and leaving out all other, in this case, useless materials, always present in compound manures.

By an analysis we may further ascertain whether a soil wants draining or not

Another question that often arises in the management of clay soils, and one that can be solved by analysis, is whether a clay may be improved or not by burning. In some cases this operation is attended with the best results, the soil being benefited to an extent often equal to that produced by a dressing of manure; in such cases this expensive operation can be advantageously employed, and the money spent upon it will be well laid out. But it sometimes happens that a clay cannot be improved by burning, because it contains no useful materials in a locked-up state, and, consequently, is unable to supply them by any amount or by any method of burning. Hence, in such a case, the operation will be useless, and the money spent upon it wasted. Analysis will at once guide us in this matter: it will tell us whether a clay will be improved by burning, and point out the proper method of conducting the process, and also the amount of benefit we may expect from it. In forming an opinion upon such questions as these we should of course take into consideration the loss of nitrogen involved in this operation, to which we have previously made reference.

Perhaps the most frequently occurring instance of practical benefit conferred by chemistry upon agriculture is manifested in the assistance it renders in connection with the question of liming. Chemistry tells us in the readiest manner whether a soil wants liming or not, and points out the best plan of proceeding if it does. If, as often happens, we have a choice of two or three sorts of lime at our disposal, it will also tell us which sort is likely to produce the best effect.

Limestones and marls vary most widely in their fitness for use in this way. Many of them contain an excessive amount of magnesia, and on this account are dangerous to use; others may contain appreciable quantities of the valuable phosphoric acid. On all these points chemical analysis will enlighten us. We may ascertain in a very ready manner if there is enough lime in a soil as follows:—Place a little of the soil after burning in a wine-glass, and add some muriatic acid (hydrochloric acid)—this is well known, and can easily be procured under the name of spirits of salt. If the earth now bubbles up or effervesces, we may assume that plenty of lime is present in the soil; but if no effect is perceptible, we may infer that it is deficient in this constituent. The lime in soils usually occurs in the shape of calcium carbonate (carbonate of lime); this, as we have seen, consists of lime and carbonic acid gas in a fixed or solid state. On adding to this combination hydrochloric acid, the lime unites with this acid and liberates its former companion—carbonic acid. This gas, in escaping from the mixture, gives rise to the bubbling up or effervescence. The test given, it must be remembered, is but a very rough one, and by no means conclusive as to the presence or absence of lime in a soil, yet it will often be found useful as a general test for that compound.

CHAPTER IV.

WATER.

All the different kinds of waters found in nature consist of real or pure water, containing different sorts and different quantities of organic and mineral impurities.

Chemically speaking, there is but one sort of water, and this can be separated by suitable means from any description of water, however impure it may be. The distinguishing qualities of rain water, spring water, mineral water, and sea water, and all other kinds of water, are imparted by the foreign matters mixed with, or dissolved in, this real or pure water. Before describing the qualities of pure water it will be well to consider the general properties of our ordinary supply and its connection with the other materials of the earth.

Water is found in three states or conditions: as a solid, in the form of ice; liquid, as generally met with; and as a vapour or in a gaseous form. In these two latter conditions water is intimately connected with the economy of nature, and especially with animal and vegetable life. Solid water, or ice, is comparatively unimportant; yet even in this shape, or rather in its conversion into this shape, water exerts a highly beneficial effect on our soils, as noticed in the preceding chapter. Although ice, or solid water, is seen only during a part of the year in this climate, it forms in the polar regions permanent rocks like granite, limestone, or other minerals. In warm or temperate climates water is generally met with as a fluid, in which condition it is intimately concerned in the operations of organized life. In every stage of the development of plants the presence of water is absolutely necessary, and in the various functions of animal life its presence is alike indispensable. In its more bulky gaseous condition water is no less useful and essential in the operations of Nature. The vapour of water forms, as we have seen, an important constituent of the atmosphere, and it is in the form of vapour, or, as we shall call it, natural steam, that water gives rise to the beautiful phenomena of rain and dew.

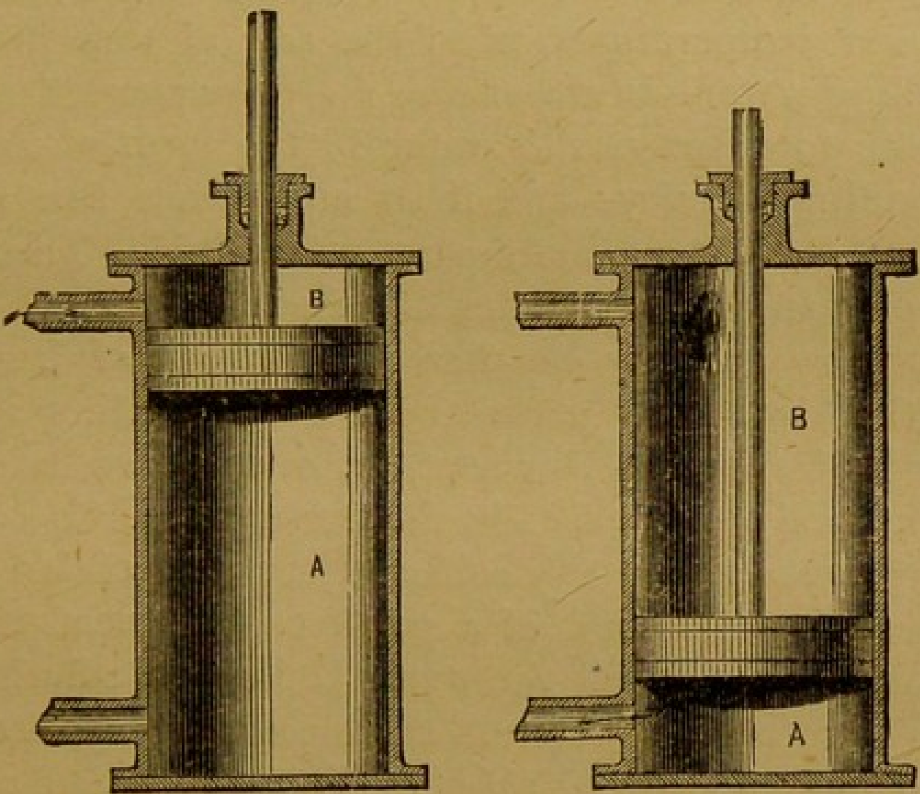
Before entering into any explanation of the manner in which these phenomena are produced from the vapour of water it will be well to make ourselves acquainted with the general properties of steam, and this we shall best do by first directing our attention to artificial steam, or that produced when water is exposed to fire. And here we may remark that this artificial steam performs a no less important part in our artificial world of manufacturing art than does the natural steam in the economy of nature, since it supplies us with an unlimited source of strength and enables us to perform tasks that would otherwise be utterly impracticable, when made to exert its power through the medium of the steam-engine.

When water is made to boil in a covered vessel, as in a tea-kettle, the water rises as steam, which quickly fills the vessel, and in a short time escapes from the spout, giving rise to a cloud of white vapour. Steam is nothing more or less than water in the shape of gas, which gas is invisible like the air. It must not be supposed that the white cloudy substance seen to issue from the spout of a tea-kettle or the escape-pipe of a steam-engine is steam: the white cloud is water in a finely-divided state, into which the steam is changed on coming in contact with the colder atmosphere. These particles of fluid water, being too small to exhibit the transparent appearance belonging to water in larger quantities, form a white opaque cloud, just as glass, which is usually transparent in masses, becomes white like flour when finely powdered.

We may satisfy ourselves that steam is really invisible, by noticing that immediately at the orifice whence the vapour issues the white cloud is not seen, it being only formed when the steam becomes mixed with the surrounding air, or, still better, by boiling some water in a glass flask, when steam will rise from the mouth while the interior is apparently empty.

When a kettle or other vessel containing water is made to boil over a fire, provided the steam can escape, it never gets hotter than the temperature of boiling water: this temperature is found to be 212° of Fahrenheit's thermometer. How is this? We know that a vessel containing no water, under the same circumstances, quickly gets much hotter, and soon becomes red-hot; why does not the kettle and water become red-hot too? Because all the heat that would make it red-hot combines with the water which passes away as steam; and as long as any water is left, all the heat the kettle receives will be disposed of in this way. Thus we may regard steam as water combined with heat. When water is converted in this manner into steam it occupies about 1,700 times more space than it did when in the form of water. Further, if by any means this steam is deprived of its heat, the water returns to its original shape, that of fluid water, and now occupies about 1,700 times *less* space than it did when in the shape of steam: the steam is now said to be condensed. Thus, by condensation, invisible steam returns to fluid water. It is on these simple facts that the prodigious power of the steam-engine depends for its action. The steam-engine is merely a machine contrived to enable the above-named phenomena to produce motion. A very brief explanation of the source of motion in a condensing-engine may not be uninteresting. A metal box is constructed, with a tight-fitting division that is capable of sliding from one end of the box to the other, which is thus permanently divided into two portions, each portion diminishing or increasing in size as the division moves from one end of the box to the other. The box we have described is the cylinder, as it is called, of the engine; the tight-fitting but sliding division is called the piston. This piston is the only part of the entire machine that the steam puts in motion; all the other parts of the engine are contrivances for supplying steam from the boiler to the cylinder at the proper time, or for communicating the motion of the piston to other parts of the machine. Let us see how the above properties of steam cause the movement of the piston.

Suppose the piston to be moved to one end or to the top of the cylinder, and the compartment marked A in the annexed engraving to be filled with steam, and that by suitable means this steam is rapidly condensed, it will now occupy 1,700 times less space; or, to be less precise, we may assume this compartment will suddenly become empty. Suppose again more steam is admitted at the other end of the cylinder, or to that compartment marked B. By pressing with all its force on the upper side of the piston, and there being now nothing on the opposite side to oppose its progress, the piston is moved forwards or downwards as the steam enters and fills this portion of the cylinder. On this steam being in its turn condensed in the same manner, and more steam being admitted to the lower compartment, the piston is moved back again to its former position ; and



so by a repetition of these acts the motion of the piston from one end of the cylinder to the other is maintained.

Without entering into any explanation of the astonishing power or strength of the steam-engine, we may remark that the force with which the piston moves depends on the pressure of the steam employed and the extent of surface the piston exposes to it. The beauty of the steam-engine lies in the fact that its strength, however vast, is perfectly under control.

Steam is formed at all other and therefore much lower temperatures than that at which water boils. Water exposed to the air evaporates and becomes steam at all temperatures ; even ice and snow evaporate to a small extent. The rate of the evaporation, however, always follows an invariable rule : it varies in proportion to the temperature, and is consequently slower when the air is cold. We have already seen that the atmosphere always contains water in this invisible or gaseous condition, and that the amount thus present in the air depends upon the temperature of the earth and the atmosphere.

The same laws of condensation affect the steam formed at these lower temperatures, as in the case of that produced from boiling water—in either case a certain amount of heat is requisite to preserve the water in the form of steam of corresponding density—and if by any means this heat is withdrawn, the water again separates as a fluid. These facts help to explain the phenomena of rain and dew.

In hot, dry summer weather, the amount of heat pervading the air is very great, and a corresponding amount of water is dissolved by this heat, or, in other words, a great deal of natural steam exists in the atmosphere. If such air comes in contact with any colder object it is cooled down, and now, being deprived of a portion of its heat, it is no longer able to retain all the water it held in solution ; so that a portion of this water is condensed, or deposited in a liquid form upon the cold object. This deposition of fluid water upon any solid object we call dew. We may produce dew at pleasure by exposing any cold object to warm and moist air. When a glass of cold spring-water is exposed to the air in summer time, a copious deposit of dew is soon formed on the outside of the glass, produced from the steam in the air being condensed by the cold glass in the manner above described. The same thing takes place when we breathe upon a looking-glass or polished metallic surface ; the water dissolved in our breath in this case furnishes the moisture or dew that is deposited on the glass or other cold surface.

In the same manner, on a larger scale, water is deposited on the cool surfaces of the leaves of plants and other exposed objects, giving rise to the pearly drops of dew.

During the day every object accessible to the sun becomes heated ; on the departure of the sun, in the evening, these objects begin to lose the heat they have absorbed during the day: it flies off or radiates in all directions, until, on their becoming cooler than the surrounding air, dew begins to fall, or, in other words, the steam of the air is condensed on the colder surfaces of the objects exposed to it.

And here we must notice another beautiful natural law that regulates the disposition of dew, and prevents it being wasted on objects that can make no use of it, thus reserving a larger quantity for growing plants, which greatly need this moisture, chiefly provided on cloudless nights. We must all have noticed that grass and herbage are often wet with dew while the earthy surface of paths and roads is still dry. This is because dew is always deposited first and in greatest abundance on those objects which cool first. The leaves of plants belong to this class of bodies ; they soon get hot on exposure to the heat of the sun, and as soon get cold again when the sun goes down. With earthy materials, as stones, gravel, and soil, the case is very different ; these substances are slow to receive heat or to become warm, but, when warm, are as slow in cooling. Hence these objects retain the heat of the day till late in the evening, and receive but little, if any, of the falling dew.

When a body of warm air, containing a great deal of moisture or natural steam, comes in contact with another body of colder air, some of the steam is condensed and separated, as in the formation of dew ; but as in this case there is no solid object to receive the particles of liquid water, it remains where separated in the shape of minute white globules, and forms what we call mists or fogs. In cold weather every breath we exhale forms in this manner a little cloud of white vapour. When we breathe on a cold glass the water of our breath separates in dew, but when we breathe into cold air it separates in the form of mist.

When a large quantity of water is separated in the same manner, at a higher elevation, the particles of moisture collect in drops, and rain is formed, which, in falling to the earth, removes the dust and other extraneous matter floating in the air; thus at the same time purifying and cleansing the atmosphere and enriching the earth.

The quantity of rain that falls in different localities varies exceedingly, being influenced by the physical character of the district, as well as by certain general laws. The chief of these laws is what we might infer from the above statements, viz., that the amount of rain is greater in hot climates than in temperate and cold ones. It is often a matter of interest to ascertain the quantity of rain that falls in a particular spot. This is done by means of an instrument called a rain-gauge, which is simply a vessel for receiving the rain from a given extent of surface, and preventing its loss by evaporation until measured in a cylindrical glass, whose divisions indicate the amount of rain that has fallen in the space exposed by the gauge. The amount of rain measured in this way is generally stated in inches, so that in reading results of this measurement we are to understand that a quantity of rain has fallen that would cover the entire surface of the ground to the depth stated.

In this country the average annual fall of rain is about 28 inches. This quantity varies in different seasons and in different parts of England, being greater on the west side of the island than on the east. At London the average fall of rain during the year is about 22 inches; at Liverpool 33 inches. The quantity of rain becomes larger as we approach the equator, and in parts of India the amount registered during the twelvemonth is as much as 190 inches, or nearly 16 feet. In our own and other temperate climates the fall of rain is pretty evenly distributed throughout the year, but in tropical climates the rain falls during periodical wet seasons, in the intervals of which, with the exceptionof occasional storms and hurricanes, dry weather can be depended on. The observance of atmospheric phenomena, constituting the science of meteorology, is a matter often too little valued by persons generally; this is the more to be regretted, as it seems probable that by cultivation this science is capable of imparting valuable practical information as to the future state of the weather. Of late years public interest has to some extent awakened to the importance of this subject, and we may hope the feeling will increase, for although the weather is considered one of the Englishman's stock-subjects of conversation, we are still very unlearned regarding it, and probably there are laws and causes affecting the weather of which we are at present quite ignorant, for even those most practised in meteorological observations appear to be at fault occasionally. Our partiality as a nation for discussing this subject, to which we just referred, cannot cause us much surprise when we consider the very varied character of our climate, which surely fully justifies the opinion of our American neighbours, that we have our weather in samples; and at times we feel glad this is so, for if some of these samples were delivered in bulk the outlook might be bad indeed.

The water of dew and rain is the purest sort of water met with in nature, but even this contains impurities—foreign matters the rain-drops have collected in their passage through the air. Some of these impurities have been already noticed as substances useful to vegetation.

Of course the rain that falls in the neighbourhood of large towns cannot be included in the above statement. As the atmosphere of these places is loaded with smoke and other abominations, it follows that the rain falling in these localities must be very remote from anything like purity.

By imitating the formation of dew, or by condensing steam in vessels where the newly-formed liquid water has no opportunity of meeting with foreign matters that can contaminate it, we obtain pure water. Whenever steam is condensed under these circumstances the resulting water is free from all solid impurities.

This operation is called distillation, and is carried on in vessels called "stills"—the same kind of vessel used for the distillation of spirits and for other purposes in the arts. The water obtained by this process is called distilled or pure water. It is distinguished by the following characters. In appearance it is much brighter and clearer, and more transparent than water as generally found in nature; it possesses an unpleasant taste, or rather its absence of taste produces an unpleasant sensation in the mouth. This effect is produced by the absence of air in distilled water. A special apparatus, known as "Normandy's Still", provides for the replacement of the expelled air, when the water is required for drinking purposes, which is constantly the case on board ship. Further, it leaves no residue or crust of solid matter when evaporated. Thus pure or real water is the basis of all natural waters, as before stated. We can imitate some kinds of natural water (as sea water or mineral water) by adding to distilled water the solid substances found by analysis to be present in the water we wish to produce.

Distilled or pure water is largely used in analytical chemistry, in medicine, and for photographic and other purposes, where even the slight impurities of good drinking-water would seriously interfere with the desired results.

Let us now proceed to make ourselves acquainted with the chemical characters of this pure water, and ascertain its composition and its behaviour towards other substances.

For a long time no one conceived that water contained anything different from itself, or, in other words, was a compound substance; but such has been found to be the case. This discovery was made by the distinguished chemist Cavendish, who at the close of the last century demonstrated that water is composed of two gases, called respectively oxygen and hydrogen. One of these gases we have already described, and would remind the reader that 16 lbs. of every 18 lbs. of water consist of the ever-present oxygen; the remaining ninth part of water consists of hydrogen, whose properties we will now briefly consider.

Hydrogen gas is invisible and colourless like the air, and, as usually prepared, possesses a slight odour. The most remarkable property of hydrogen is its extreme lightness: it is about fourteen times lighter than the air, and consequently is the lightest substance known.

Hydrogen differs from all the gases we have so far described by being inflammable; it takes fire when a light is applied to it, and burns with a pale flame, scarcely visible in the daylight, but of intense heat.

Hydrogen is an abundant material of the globe, but is never found in a free or uncombined state. As a fluid we have seen it forms a ninth part by weight of all the water of the globe; and in a solid form it occurs in considerable proportions in animals and vegetables. In the dry substance of hay, roots, wheat, etc., about 6 lbs. of every 100 lbs. consist of hydrogen. In food of all descriptions hydrogen is also present, as well as in tallow, oil, wood, coal, and other materials used for fuel.

We have mentioned as one of the properties of hydrogen its inflammability. Whenever hydrogen is burned it is undergoing rapid oxidation, or combination with oxygen, in a manner precisely analogous to that described while speaking of carbon and carbonic acid gas. The result of this combination is water, which is always found wherever hydrogen is burned. Hydrogen is generally the companion of carbon in all its adventures throughout the artificial and natural operations going on around us. For instance, in combustion, respiration, decay, and the growth of plants, hydrogen and carbon are always found in company, and performing the same kind of purpose. The combustion of hydrogen is accompanied by the phenomena of flame. All the flames usually met with, as those of our fires, candles, or lamps, are produced from the rapid oxidation of hydrogen or its compounds.

Thus our breath contains water as well as carbonic acid gas, which, like the latter, is produced by the combination of the materials of our food with the oxygen of the air we inhale. The combination of hydrogen with oxygen in our lungs is also attended with the liberation of heat. This heat, with that resulting from the formation of carbonic acid, sustains the proper warmth of our bodies. The presence of water in our breath may be shown by blowing through a glass tube; the water is condensed as dew, and soon collects in drops and trickles down the sides of the tube.

By means of a powerful current of electricity water may be separated into its constituent gases, oxygen and hydrogen. The quantity of hydrogen produced is always twice as much by measure as that of the oxygen. Hence we learn that two measures of hydrogen are combined with one measure of oxygen to form water. This decomposition of water by electricity is one of the most beautiful chemical experiments.

To decompose water we have always to employ powerful chemical agents. This is because the gases are held together so firmly as to resist all ordinary means of separation. Yet, difficult as the operation is to us with all the appliances of science, the same operation is constantly going on in the leaves of the humblest plant. Plants decompose water as well as other still more powerful mineral combinations, as sulphuric acid, phosphoric acid, carbon dioxide, etc., in the cells of their leaves. From the water decomposed in this manner plants derive the hydrogen, which, as above stated, forms a considerable portion of their substance.

Pure water can also be formed by burning together its constituent gases, oxygen and hydrogen, in the proportion above named. If this mixture is made to burn slowly by a suitable apparatus a flame of intense heat is obtained, called the oxyhydrogen blowpipe-flame; if, on the contrary, any quantity of the mixture is lighted, it explodes with great violence: hence this mixture is called explosive gas. The production of a compound in this manner, by putting together its constituents, is called synthesis; the reverse of this process, or the taking apart, is the more common chemical operation called analysis. When a compound like water, for instance, will admit of its composition being demonstrated by both these operations, its composition is established with the greatest certainty. In this manner we can imitate the production of a great many mineral products, but organic substances, or those of animal or vegetable origin, present much greater difficulties to the chemist; indeed, in former years the supposed impossibility of artificially producing such compounds was regarded as an important distinction between organic and inorganic substances.

Another property of water must now be noticed, which, although not strictly a chemical quality, is yet more than a mechanical one—we allude to the solvent power of water, or its property of taking up and dissolving other substances. When we mix salt or sugar with water, it dissolves, and soon entirely disappears. The sweet taste of the sugar or saline taste of the salt is transferred to the water, which is now said to be a solution of the sugar or salt.

In this way a large number of substances can be dissolved in water to a greater or less extent. Sugar and salt are easily-soluble substances, because a small quantity of water is sufficient to dissolve a considerable amount of either; but many of the substances that are soluble in water are not readily so, a small quantity only being dissolved by a large quantity of water. It is this solvent power of water that prevents it being found in a pure state in nature. Even the rain-drops in falling through the air meet with certain soluble substances and dissolve them; hence rain-water, although the purest kind of natural water, yet contains substances dissolved in it. Again, the rain-water, in soaking through the earth, meets with mineral matters, some of which are dissolved and carried away. Thus the water of streams and rivers always contains some of the soluble matters of the ground through which it has passed.

When chalk or earth is mixed with a considerable quantity of water, the bulk of the solid soon settles to the bottom, but the liquid remains muddy; and even after standing some time the water is still far from clear. The fine particles mixed with or suspended in the water in this manner must not be confounded with substances that are dissolved in it. When solid matter is merely mixed with or suspended in water it can be separated from the fluid by long standing or by filtering; on the contrary, a solid when in solution will never settle by standing, neither can it be separated by straining, because it passes through the finest pores of the filtering material, and will be carried wherever the water can penetrate. Moreover, solid particles, when merely suspended in water, can always be recognized by our sight—even when their quantity is minute, they are indicated by a muddiness or want of transparency in the water—whereas solids that are dissolved in a liquid do not in the least interfere with its transparency and brightness.

It is in the character of a solvent that the value of water in relation to organic life is most displayed. As we shall learn when inquiring into the structure of plants, it is by means of this property of water that they are supplied with a large proportion of the materials requisite for their growth. In the bodies of animals it is also by means of this property of water that the nourishing solids of the food are conveyed to every part of the animal frame.

To continue the above-mentioned familiar example of solution: if we evaporate, or boil away until none is left, the water to which salt has been added, the latter may be recovered in precisely the same condition as before dissolving in the water. In the same manner all natural waters leave behind, when evaporated to dryness, as this process is called, the solids they had dissolved. We may avail ourselves of this fact to ascertain in a rough manner the relative purity of different sorts of natural water. We can apply this test by evaporating two or three drops of the sample to be tested on a slip of window-glass, or a bit of tin-plate, holding it over a lamp or candle, and, if the former, moving it about to prevent cracking. The water is soon volatilized, and leaves behind all the solid impurities it contained. These are left as a crust or residue on the glass, which is of course abundant in proportion as the water is impure. Pure or distilled water, tested in this way, will be found to leave no residue; rain-water will leave but very little, river-water more; spring-water generally yet more than the waters of streams or wells; while sea-water will leave the largest quantity of solid matter. By this test we may satisfy ourselves that clearness and transparency are no criterion of the purity of water. In this manner we can judge of the amount of solid matters dissolved in water, and of course learn something respecting its character or quality.

Rain-water, river-water, and sea-water, and some other sorts of natural waters, differ greatly in their qualities. The two former can generally be used for domestic purposes, while sea-water is always totally unfit for drinking in all parts of the world. The water of springs varies considerably in different localities. This is because the rocks and strata through which spring-water passes vary most widely in the quantity and quality of the soluble matters they contain. If a stream of water finds a channel through a bed of rock or mineral containing some particular soluble substance in large quantity, the water dissolves the substance and partakes of its qualities. In this way the various mineral waters are formed.

Water can also dissolve gases as well as solids; the refreshing taste of spring-water, and, in a less degree, of other kinds of natural waters, is due to the gases dissolved in them. These gases found dissolved in water are generally carbonic acid gas and those of the atmosphere. Other gases are occasionally found in spring-water, which impart to it peculiar qualities. For instance, the water of Harrogate is impregnated with an offensive gas called sulphuretted hydrogen. The prevailing gas found dissolved in spring-water is carbonic acid gas ; and it is somewhat strange that this gas, although injurious to animals when inhaled, seems to exert a contrary effect when taken into the stomach, being at least harmless, if not beneficial, when received in this manner.

We swallow large quantities of carbon dioxide dissolved in the beer we drink. The freshness of recently-drawn beer is due to the presence of this gas ; bottled beer, champagne, and other effervescing drinks contain a large quantity of carbonic acid gas dissolved in them. On liberation from the closed bottles where these liquids are confined, a part of this compound escapes, and gives rise to the bubbling up or effervescence.

On boiling, the gases dissolved in water are expelled. It is for this reason that water, after boiling, is flat and insipid to the taste ; for the same reason, also, distilled, or pure water, is actually unpleasant to drink (page 110).

Water dissolves and also holds in suspension organic matter of animal and vegetable origin. The green colour of the stagnant water of ponds and ditches is due to substances of this kind in different stages of putrefaction ; and as these impurities are generally accompanied by others still more offensive, as organisms of various kinds, water of this sort is wholly unfit for domestic purposes.

We will now enumerate the more interesting properties of each of the common kinds of water.

RAIN-WATER is, as we have said, the purest sort of natural water, and if collected in an open district, in a clean vessel, before it comes in contact with the roofs of houses, or other sources of contamination, it is nearly pure water, and contains only those foreign matters that are found floating in the air. It is to the presence of certain of these, added to the uniform and gradual distribution of water of the same temperature as the air, that the refreshing effect of rain on growing plants must be ascribed.

The most important connection of water with agriculture is of course in the form of rain. In this country, where prolonged drought is of rare occurrence, it is difficult to realise the full value of rain, and its influence on the produce of the farm ; we may, however, form some idea of it by remembering the well-known truism that the weather has more effect on our crops than all we can do by manures, cultivation, etc. Of course, by weather we include the all-important sunshine ; but this is of little use without sufficient moisture.

Rain acts not only by supplying the largest constituent of all cultivated crops —including cereals in their early stages —but also by contributing small, but important, supplies of nitrogen to the soil, as previously explained.

A common estimate of the disposal of the water falling as rain is, that one-third is evaporated, one-third taken up by crops, and one-third sinks into the subsoil. This must be taken as an average much depending on the character of the season. Of the quantity of water brought down in the form of rain, a calculation shows that one inch yields in round numbers 100 tons to the acre, each ton being equal to about 224 gallons.

Unfortunately, we often get rain either in too large or too small quantities ; in other words, a continuance of dark and gloomy rain-storms, with insufficient sunshine, as in wet seasons, or the dusty and thirsty ground, with superabundant sun, of dry ones. When drought prevails we think we could not have too much rain, while in times of flood we long for its cessation as the greatest of blessings—both instances of how good things become evils in excess ; or, in other words, within what narrow limits of natural changes our welfare lies. Continuous rain has an injurious effect on the soil, chiefly perhaps by washing out the nitrates, one of the most valuable plant-foods, as before explained.

In this country we rarely suffer from extremes in this way, but in some of the Colonies and India the rainfall is of the utmost moment, and makes all the difference between prosperity and dearth, or—in India, etc.—often between life or death, as shown by the periodical famines consequent on deficient rainfall, although these calamities are now almost averted by the resources of modern railway transport, by which supplies of food from external sources become available. In Australia, also, and the Cape scarcity of water is almost a chronic evil; and we hear of the loss of thousands, or even millions, of sheep and cattle from this cause. As it is said water can be found in most places by boring, it is to be hoped an extended sinking of wells, or even the use of tube wells, which would seem to be suitable, may improve this state of things.

It is pleasing to read that in India, Australia, and Egypt, irrigation works for conserving the rainfall are now receiving more attention than formerly, and there can be no question that such works afford one of the most useful objects on which labour and capital can be expended.

The latest thing in connection with rain is its attempted artificial production in the United States. While it would seem obviously futile to attempt to bring rain out of a cloudless sky, it would appear by no means unlikely that at times when rain-clouds are lowering and all but breaking, as they often do during seasons of drought, artificial concussions in the upper regions of the atmosphere (which seems to be the principle relied on) might be attended by the desired result.

Within the last few years an apparatus of a very ingenious character for storing rain-water has been introduced, which should, if found to work satisfactorily in every-day use, prove of great value, for by its means the water falling first upon any surface with which it is connected is rejected, being turned into a drain or otherwise disposed of. In this way all dirt is excluded from the storing-tank; after a while, however, the apparatus "cants", and conducts the clean water into its proper receptacle, thus furnishing a good and wholesome supply for all purposes—subject, of course, to that intended for drinking purposes undergoing filtration.

THE WATER OF STREAMS AND RIVERS contains a great many substances in solution, collected from the soil through which it has passed; and the qualities of this kind of water will, of course, be influenced by the character of the land from which it has drained. The water of streams and rivers is occasionally found more or less muddy, and containing solid matter suspended in it. This mud is the finer particles of the soil, washed up and carried away from the land over which it has flowed: on standing, these solid particles are again deposited. In this way we can to some extent account for the good effects generally seen to follow the flooding of land by water, either naturally, as on the banks of rivers subject to inundation, or artificially, by the process of irrigation. But the deposition of mud is not sufficient to account for the striking improvement often observed in land that has been exposed to the action of water. Water acts in this way chiefly through the substances dissolved in it. These will generally be the salts of lime, potash, phosphoric acid, sulphuric acid, and other mineral matters that are able to promote the growth of plants. As it is known that earth, especially clay, is capable of extracting from water any fertilizing salts it may contain in solution, and as many natural waters contain appreciable quantities of these solids dissolved in them, we can in this way account, to a great extent at least, for the increased fertility consequent on the flooding of land by water. Again, an important mechanical effect is exerted by water in large quantities upon land.

By saturation with water, the ground will be consolidated, and its particles become better incorporated, so that on the withdrawal of the former a loose soil will be left in a better mechanical condition than it was before the water was admitted. Again, the air will now penetrate more freely to all the cavities of the soil vacated by the water, and will act more vigorously in decomposing the organic and mineral substances there present; thus rendering available a more copious supply of food to the growing plants. The fact of timber and other organic matters decaying most rapidly when alternately immersed in water and exposed to the air, may help to explain this effect of water in the process of irrigation.

Rain-water and river-water are generally "soft" waters; that is to say, they contain little that interferes with their use in washing. When soap is used in soft water, it dissolves, and exercises its cleansing effect in the following manner:—Soap is a weak combination of fatty matter, generally tallow, with some alkali, as soda. On dissolving in water, the alkali of the soap, in virtue of the property already noticed as common to all alkalies, dissolves the animal matter of the dirt, and at the same time a thin surface of the skin to which foreign matters are attached; the violent action of the alkali is subdued and modified by the fatty substance also present.

SPRING WATER generally contains a larger quantity of mineral matters than those from the sources mentioned above; it also holds more gases in solution. The prevailing solid of spring-water is lime, or more properly, calcium carbonate (carbonate of lime); and the gas with which spring-water is usually impregnated, and which gives rise to its sparkling appearance and pleasant taste, is carbonic acid gas.

It is this lime dissolved in spring-water that renders it "hard" and unfit for washing. When hard water is used with soap, the lime absorbs the soap as fast as it dissolves, and forms with it an insoluble compound; under these circumstances the soap is unable to exert its ordinary detergent properties. Hard water can only be made soft by removing the lime that it contains. This can generally be done (1) by exposure for a considerable time to the air; (2) by boiling; (3) by adding soda, or rather carbonate of soda; (4) by adding lime-water, or caustic lime dissolved in water. Before we can understand how the water is "softened" by these means, we must state more precisely the cause of the "hardness".

It will be remembered that carbonate of lime, or chalk, is insoluble in water; it separates from water as soon as formed, as in the experiment for showing the presence of carbonic acid in the breath.

If, however, more carbonic acid gas is added to the water than will form chalk with the lime, the chalk now redissolves in the water. We may convince ourselves of this fact by extending the experiment above referred to. If the carbon dioxide produced by limestone or marble is made to pass through lime-water, it first forms the white milky particles of chalk, but if allowed to pass through for some time after the chalk is formed, the latter dissolves again—it disappears, and the liquid becomes clear. Thus we learn that water containing an excess of carbonic acid gas is capable of dissolving a solid substance that is otherwise insoluble; in the same manner many other insoluble compounds are rendered soluble by carbonic acid. This property of water impregnated with carbonic acid is especially deserving of notice, as it is intimately concerned in the supply of several of the mineral-food constituents to plants.

On boiling the clear solution of chalk obtained by the above experiment, the excess of carbon dioxide is expelled, and the chalk again separated in an insoluble form, or is precipitated, as chemists say. Most hard waters contain chalk dissolved in this manner by carbonic acid. When they are boiled, this gas is expelled, and the chalk is separated. In this way is explained the deposition of calcareous matter in our tea-kettles and the boilers of steam-engines; whenever spring-water is boiled, an incrustation is generally deposited from this cause. The same effect takes place more slowly when the water is exposed to the air: the excess of carbonic acid gas escapes, and the carbonate of lime is separated.

The softening of hard water by the addition of lime (ridiculous as it may at first seem to add lime to water already hard from the presence of this material) may be explained as follows :—The caustic lime added takes up the excess of carbonic acid gas which keeps the carbonate of lime in solution, to form more carbonate of lime; which, with that originally present in the water, is now separated, and settles by standing. This means of softening water must be cautiously employed, since the addition of too much lime does more harm than good; it is, however, with proper care, a valuable means of softening water, and is extensively adopted on a large scale. These methods of treating water can only be employed when, as is more commonly the case, its hardness is due to the presence of carbonate of lime. Hard water is occasionally found in which calcium sulphate (sulphate of lime), or plaster-of-Paris, is the cause of this quality. In this case the use of some alkali like potash or soda is the only remedy. The addition of these substances in all cases greatly facilitates the action of the soap; hence the practice of adding pearl-ash or soda to water in washing.

Spring-waters that contain in solution substances that render them unfit for domestic use constitute the mineral and medicinal springs. Of these the chalybeate springs are most common; they usually contain a salt of iron, called ferrous carbonate, held in solution by carbonic acid. Others contain magnesium sulphate (sulphate of magnesia), sodium sulphate (sulphate of soda), etc.; and a few contain substances more valuable as medicines.

WELL WATERS vary in quality between spring and river water. While some wells are supplied by natural springs, the greater number receive their supply from the drainage of the surrounding soil. From the stagnant condition of well-water, it is generally of inferior quality to that of rivers or streams, and is often very impure owing to contamination with drainage from farmyards, cesspools, imperfect drains, etc., and not unfrequently dangerous to health, many cases of mysterious illness being traceable to this cause. For this reason, in sinking wells, especial care should be taken that a proper distance intervenes between them and the drains from stables, or dwelling-houses, and all other sources likely to contaminate the water of the well. Too much stress cannot be laid upon this point under all circumstances, but evidently in the case of porous soils any risk is greatly increased; and although water from a well may be harmless for some time, even when situated dangerously near a source of contamination, we can never say how long it will remain so. The foul matter issuing from broken drains, cesspools, etc., is oxidized in passing through a sufficiently large amount of earth, and any finding its way into a well will do so in a greatly altered and probably harmless form, or organisms of disease may not be present in such drainage, when no immediately apparent evil results would be likely to follow; but a time will probably come when the organisms referred to are present, or the earth become so loaded with matter that it can no longer exert its beneficial influence; or, again, sudden floods may arise and wash impurities into the well so rapidly that any natural process of purification is unable to act completely upon them during their passage through a relatively small quantity of soil, hence the importance of placing our wells as far as possible from any source of danger. Well-water and that from other sources often owes the greater part of its impurities to the solid matters floating or suspended in it. In these cases filters may be used with great advantage; but it must be remembered that filters are powerless to remove any kind of impurities dissolved in the water. We should nevertheless subject all water used for direct drinking to filtration, which removes all the mechanical or suspended impurities mentioned above, but, to insure greater protection, particularly during the prevalence of any disease in epidemic form, the method of boiling and filtration previously referred to is greatly to be preferred, and should be adopted whether we suspect the quality of our water or not. When filtering alone is considered sufficient, those filters in which the water passes through porcelain, or other material with extremely fine pores, will probably be found very serviceable.

Even for animals, the filtration of water supplied to them would doubtless be attended with benefit, as in the case of water from ponds, which in summer are often loaded with living and other impurities; for there is every reason to believe that considerable harm has been inflicted upon stock by the extremely foul character of the water they are sometimes compelled to drink or else go without any. Every precaution, too, should be taken against spreading disease by means of eating and drinking vessels of all kinds; those used for infected animals should never on any account be allowed to contain food intended for healthy beasts: indeed, the former should be entirely isolated. We believe much good might be accomplished were more attention paid to details of this nature.

The complete analysis of water is a lengthy and difficult process, requiring the application of much skill and experience, but an examination sufficient to form an opinion as to its fitness for domestic use can be made at small cost.

Sea Water differs from all other sorts in being totally unfit for domestic purposes, and by the large amount of soluble matters it contains. Of these, we all know that common salt is the most abundant; 1,000 lbs. of sea water contain about 35 lbs. of solid matter, and of this quantity 27 lbs. are common salt. A great number of other soluble substances exist in sea water; in fact, the sea is the common receptacle for all the soluble matters of the globe. Water, in the shape of vapour, is constantly rising from the surface of the sea, and is carried over the land as clouds; these sooner or later discharge this water in the shape of rain, and this, in its passage back to the sea by streams and rivers, bears with it a quantity of soluble matter derived from the soil through which it has drained.

Notwithstanding the great impurity of sea-water, it may be purified by distillation. A knowledge of this fact might have saved numbers of persons from intolerable suffering, and even death from thirst, when deprived of fresh water at sea. A distilling apparatus might be constructed by almost anyone on an emergency from a tea-kettle, or other vessel of the sort; and the only limit to the quantity of drinkable water that could now be obtained would depend on the amount of combustible material at command.

Water is decidedly one of the most valuable of Nature's gifts; it not only contributes to our happiness and comfort in so many different ways, but is intimately associated with our very existence.

In every stage of the production of every sort of agricultural produce, water plays an important part: in the germination of seeds, the subsequent growth of the plants, the development of their seeds and bulbs, the presence of water is absolutely necessary. In ordinary articles of diet water forms a proportion surprisingly large to persons unaccustomed to chemical wonders. In raw meat 78 lbs. of every 100 lbs. are water; potatoes contain 72 per cent. of water; in cattle-food a still larger quantity (in swedes, for example, there is about 89 per cent. of water, while in white turnips the proportion of water is often as high as 91 per cent., or 9 lbs. only of real food in 100 lbs. of turnips). After these statements we may not be surprised to hear that the greater part of our own bodies consists of water: a man weighing 154 lbs. contains 116 lbs. of water and 38 lbs. of dry substance.

CHAPTER V.

CHEMISTRY OF THE PLANT.

HAVING now made ourselves acquainted with the composition of the soil, of the air, and of water, the sources whence plants derive the materials of their growth, let us trace the formation, from these materials, of the products of vegetable life, particularly those which constitute the food of man and animals. When a growing plant is removed from the soil and exposed to the sun and wind it quickly droops, withers, and finally shrinks up to a much smaller bulk and weight than it possessed when recently gathered. This loss of substance is due to the evaporation of the water, which, as before hinted, forms so large a proportion of all living vegetables. Again, if this diminished substance of the plant left after drying is exposed to fire nearly all of it burns away or disappears, leaving nothing behind but a little ash or mineral matter. The portion of the plant that suffers destruction by burning is called the organic part, because it consists of various compounds produced by the process of vegetable growth from materials supplied from some of the sources above mentioned, although we can no longer distinguish between organic and inorganic compounds by saying the former are the products only of the action of "life", either animal or vegetable, as we have already explained. The constituents of this organic part of the plants are carbon, hydrogen, and oxygen, with small quantities of nitrogen and sulphur. By heating, these materials pass off as smoke and invisible gases, hence the disappearance of the greater part of the plant on burning. These components exist in the plant, grouped together in all sorts of positions and proportions, giving rise to the numerous substances of vegetable origin we see around us. Wood, starch, sugar, fat, linen, cotton, and a multitude of other equally well-known materials, consist of nothing but the three former of these elements, in each case differently arranged. The fourth constituent, nitrogen, occurs chiefly in the choicer parts of plants—the seeds, and other parts of their structure most valuable as feeding materials.

The ash left on burning plants consists of the mineral substances extracted from the soil during their growth ; and these, not being volatilized by heat, are left behind after the vegetable matter is consumed. This portion of the plant is called the mineral or inorganic part of it, and consists of nearly all the materials described as belonging to the soil. The general composition of plants—that is, their proportion of water, organic matter, and ash—will be understood by a glance at the following table :—

GENERAL COMPOSITION OF VEGETABLE PRODUCE.

(*Stated in one-hundred parts.*)

	WHEAT.		TURNIPS.		CABBAGE
	Grain.	Straw.	White.	Swedish.	
Water	12.26	14.23	90.43	89.46	86.28
Organic or combustible matter, consisting of carbon, hydrogen, oxygen, nitrogen, with a little sulphur...	85.99	80.30	8.95	9.82	11.85
Ash or mineral matter, consisting of nearly all the constituents found in the soil	1.75	5.47	.62	.72	1.87
	100.00	100.00	100.00	100.00	100.00

For a long time no notice was taken of this small quantity of ash left on burning plants ; no one supposed that it was in any way essential to the structure of the plant, or had taken any part in its development. Until comparatively recently the impression concerning the ash of plants seemed to be that it consisted of mineral substances accidentally conveyed to them from the soil. This, however, is not the case. We now know that this ash, or the mineral constituents, although smaller in quantity, is nevertheless as important as, or even more so than, the more abundant organic or vegetable portions of the plant ; that their presence is not accidental, but necessary to the formation and the existence of the vegetable productions in which they are found. Hence the separation of the constituents of plants into organic and mineral groups is altogether an imaginary division, and made only to suit our convenience in studying their composition. It must be recollected that no such division exists in nature, both mineral and organic substances being equally indispensable to the development and to the identity of the several vegetable compounds of which the plant is built up; that, in short, vegetables, or more strictly the organic principles of vegetables, are combinations of large quantities of certain constituents of the air and of water with small quantities of the mineral compounds of the soil.

That the ash or mineral constituents of plants is really essential to their growth, and not, as formerly supposed, merely of accidental occurrence, is established by the following facts:—

1. The proportion of ash or inorganic materials, although subject to slight variations that need not be accounted for here, is generally constant in members of the same order of plants, and also in their various parts. This applies to mature crops chiefly.

2. That while certain mineral substances are common to several families of plants, their amount and relative proportion vary with each separate tribe; or, in other words, particular inorganic materials predominate in particular tribes of plants. For instance, in the cereal crops, as wheat, barley, oats, etc., the distinctive mineral present is silica. Again, in plants of the pea tribe, or leguminous plants, as clover, pease, beans, etc., lime or potash is the predominating mineral constituent.

3. These differences in the composition of the ash of plants are not materially affected by the character of the soil on which the plants have grown. To continue these examples, the wheat plant is always found to contain a large propor-

tion of silica, although it may have been raised on a lime soil, and the clover or pea will also contain large proportions of lime, even when grown on a sandy or clay soil. On this fact is based the classification adopted for cultivated plants, in which they are arranged in groups, named after the prevailing constituent of their ash, and called silica plants, lime plants, potash plants, etc.

4. Since each tribe of plants requires more particularly a certain kind and a certain quantity of mineral matter for its development, it is clear that unless a soil is capable of furnishing these materials in sufficient quantity, this tribe of plants will not flourish upon it; and if the soil is wholly destitute of the particular mineral substances required by the plants, they refuse to grow, or, at least, to come to perfection.

These remarks will be better understood by a careful examination of the following table:—

COMPOSITION OF THE ASH OF

	Wheat. Straw.	Wheat. Grain.	Clover. Leaves and Stems.	Swedish Turnips. Bulbs.
Potash	12 28	29.94	24.928	36.98
Soda	.60	3.90	3.039	6 76
Magnesia	2.74	12.30	12.176	3.61
Lime	6.23	3.30	34.908	11.14
Phosphoric acid	5 43	46.00	7.352	9.74
Sulphuric acid	3.88	.33	3.718	12 43
Silica	67.88	3.35	1.313	3 43
Ferric oxide (Peroxide of iron)	.74	.79	1.470	1.09
Sodium chloride	.22	.09	11.096	7.85
Potassium chloride	—	—	—	.59
Carbonic acid	—	—	—	6.38
	100 00	100.00	100.000	100.00
Percentage of ash in the dry produce ...	6.02	1.93	10.53	5 91

The mineral constituents of the ash, and the carbon, hydrogen, oxygen, and nitrogen of the organic portion, are said to be the ultimate principles of plants, because these are the fundamental constituents of all plants, into which they can be separated by chemical analysis. These materials, existing in the plant, are not endowed with the same properties we find they possess when forming part of the atmosphere, of water, or of the soil from which they have been derived. All their individual properties are put aside, and by the functions of vegetable life they are arranged together in new forms, possessing new properties, altogether distinct from those of any of their combinations we have hitherto described. These compounds are called the proximate principles of plants, and they constitute the natural components of which all varieties are formed. The vegetable productions used as food for man and animals are to be regarded as mixtures of those proximate principles. In order that we may clearly understand the difference between the ultimate and proximate principles of plants, and the full meaning of the latter term (a distinction that is very necessary to be understood), let us mention an example. The bulk of some matured plants consists of woody fibre; this woody fibre, or simply wood, is the same substance, whether it occurs in close masses, as in the stems of trees, or as fibrous threads in the stems of smaller plants—the flax-plant, for instance. In this latter form we call it flax, and, when manufactured, linen. In the former case we call it timber of various sorts; but, from whatever source derived, this woody fibre, when separated from foreign substances with which it is always naturally mixed, possesses the same qualities, and is chemically identical. Woody fibre is one of the most abundant of the proximate principles of plants. If we further examine this substance and subject it to other more powerful means of separation, we find it to consist of carbon, hydrogen, and oxygen, with a small quantity of mineral matter, or ash. These are its ultimate constituents. Of the same character, but in less abundance, we find hosts of other compounds in the vegetable world; but, luckily for us, the number of them essentially concerned in the vegetable productions used as feeding-materials is not large. While nearly every tribe and variety of plants contains some principle peculiar to itself, which gives rise to the distinguishing characteristics of its produce, such as flavour, they also contain a number of other principles, which vary to some extent with each order, common to all plants. Compounds of the former class generally constitute but a minute proportion of the plant's substance, and may be omitted in most practical considerations ; the latter kind are those of which its bulk and weight consist, and by which its value as a feeding-material is chiefly regulated.

The number of proximate principles to which we need direct our attention is about twelve or fourteen. These are divided into two classes :—1. Principles which consist of the three elements, carbon, hydrogen, and oxygen (exclusive of the small quantity of ash), as in the above-mentioned example, woody fibre. These are called non-nitrogenous or carbonaceous principles, and, with one or two exceptions, are also called respiratory, heat-giving, or fat-producing substances, on account of the part they perform in the animal organism. 2. Principles which contain, in addition to the elements just mentioned, nitrogen, as well as in certain of them smaller quantities of sulphur. These compounds are called nitrogenous principles, the most valuable of their number being distinguished as albuminoids, on account of their similarity in composition to albumen (white of egg), or flesh-formers, as indicating the important office they perform in relation to animal life. It is these which contain the sulphur just referred to.

Non-nitrogenous, Heat-giving, and Fat-producing Principles of Plants.

The compounds belonging to the group of carbo-hydrates and other fat-giving, etc., principles, to which we need direct our attention, are the following :—

FIBRE has already been noticed. It is by far the most abundant of vegetable products, as it forms a great part of most matured plants; in wheat, oats, grass, and all cultivated crops, it is more or less abundant. Woody fibre, in a matured state, when a substance called lignin is most abundant, is almost useless as a feeding-material; it simply passes unchanged through the animal system, and in the case of our domestic animals forms the chief bulk of their solid excrement: hence the amount of this substance materially affects the value of feeding-materials. The imperfectly-formed woody matter, as it exists in young plants and in the succulent portions of older ones, is digestible in the stomachs of animals, and seems to be nearly as useful to them as the other members of this group. As it is found that the proportion of indigestible woody fibre greatly increases as the plants reach maturity, we can, to some extent, account for the superior value of hay that has been cut early, in comparison with that made from plants which have been allowed to reach a more adanced period of their growth.

STARCH forms a considerable portion of flour and meal of every sort; it also occurs in potatoes, carrots, and other roots. Sago, tapioca, arrowroot, etc., consist almost entirely of starch. In a dry state, starch forms white glistening particles, which, when examined under the microscope, present the appearance of little groups of knobs or clusters of irregularly-shaped bodies, which are found to possess a distinctly organised structure, and whose appearance varies with the plant from which they are derived; the largest, taken from potatoes, are about $\frac{1}{300}$ inch in their longest diameter, and the smallest, from rice, equal about $\frac{1}{3000}$ inch in diameter. Starch is insoluble in cold water; by heating, starch is converted into a sort of gum called dextrine. This substance is at present manufactured on a large scale, and has nearly superseded the use of the natural gum-arabic.

SUGAR is present in the juice of most plants, and in particular plants, as the sugar-cane, maple-tree, and sugar beet, occurs in a quantity sufficient to admit of its profitable extraction. Of the plants usually cultivated, sugar occurs in largest amount in the carrot, mangel, swede, and turnip.

GUM, MUCILAGE, PECTIN, are all more or less abundant in cultivated produce, and possess several properties in common. Mucilage occurs in particular seeds, as in linseed; the gelatinous mass obtained on mixing linseed meal or linseed cake with water, is caused by the mucilage of the seed. The foregoing compounds are carbo-hydrates.

OIL OR FATTY MATTER is found in the seeds of many plants, as linseed, rapeseed, etc. These seeds, even when deprived of the greater portion of their oil by pressure, still retain enough of this substance to render them useful as a feeding-material : the various oil-cakes used for fattening cattle consist of seeds in this condition.

Regarding the value of these several substances in the animal organism, oil would appear to occupy a position between two-and-a-quarter and two-and-a-half times greater than starch, while that of indigestible fibre can be only of an indirect nature. The other members of the group approximate far more nearly to one another in nutritive value.

Of these compounds the greater part of the dry substance of vegetable productions used for food consists, and when received into the animal system they become the fuel before noticed as necessary for sustaining the animal heat in the process of respiration. It will be remembered that by means of this process animals effect the combination between materials present in the blood and the oxygen of the atmosphere ; and as in this action a certain quantity of heat is liberated, the amount requisite for animal functions is kept up. These materials, which may with great propriety be called animal fuel, are the starch, sugar, oil, etc., in food. A large portion of the food consumed by animals is required simply for the purpose of supplying heat to the body by undergoing oxidation in the lungs; other purposes for which it is needed being the performance of mechanical work and building up the waste of tissue, these forming the normal requirements of adult animals. For the production of heat and mechanical work, so long as the latter about equals the amount which the animal is accustomed to perform, these non-nitrogenous principles seem to be as well suited as the albuminoids. When growth, extra waste of tissue, or any special product, as milk, are involved, we must follow different lines. The products of this oxidation are the same as if these materials had been burned; in either case, carbonic acid gas and water are formed, which, in the case of animals, pass off in the breath exhaled. Thus a great part of the food taken into the animal system is disposed of through the lungs, and its constituents are returned to the atmosphere in the same condition as before being manufactured by the plants. When a larger quantity of this kind of food is taken by an animal than is required to sustain the proper heat of its body and perform the requisite amount of work, the excess is stored up in the shape of fat. Thus an animal supplied with ample food, confined in a small space and taking no exercise, becomes fat by the formation of this material from the food that would otherwise be consumed by exertion. All of these respiratory compounds can thus be converted in the animal organism into fat, but with different degrees of facility; the nearer they approach to the character of fat, the sooner and more readily they assume this form when digested by an animal. For this reason, vegetable fats and oils are found most conducive to the formation of fat when consumed by animals. This we can easily understand. We should naturally expect that the conversion of linseed oil, for instance, into animal fat, would be a simpler process than the production of the same material from sugar or starch. In this way is explained the superior efficacy of the different oil-cakes, compared with other kinds of food, in the fattening of cattle. On the contrary, when the quantity of respiratory compounds is deficient in the blood of animals, either from insufficient food being supplied, or, what amounts to the same thing, inability to digest that taken into the stomach, the animal system suffers from want of heat, and cold is felt; the warmth required for the proper maintenance of its functions is wanting, and the health more or less interfered with. Moreover, unless a due amount of combustible matter is present in the lungs for the oxygen of the air to act upon, the surfaces of the lungs are themselves wasted by this element As the heat of the body is in direct proportion to the quantity of respiratory compounds consumed in the lungs, and as a certain amount of heat is necessary for the proper performance of the functions of the animal system, it is clear that a healthy animal will require more heat, and consequently more food, in cold weather than in warm weather. In the same manner may be explained the well-known fact that animals exposed to cold winds consume more food than when sheltered.

Thus we may conclude that the members of this group of organic compounds, when used as food, are able to supply the animal system with warmth, to produce mechanical force, also to furnish material for the formation of fat, but are incapable of imparting constituents for building up the bones, muscles, nerves, and other parts of the animal frame, which of course constantly require renewing, and for this purpose the albuminoids and mineral constituents are essential. For this reason they do not of themselves constitute wholesome food. An animal fed on these substances only, quickly perishes for want of the—

NITROGENOUS OR FLESH-FORMING PRINCIPLES OF PLANTS.

As already mentioned, the nitrogenous principles of plants constitute the smaller and choicer portion of all vegetable substances used for food. These compounds differ from the preceding ones in having a less simple composition. They contain, in addition to carbon, hydrogen, and oxygen, nitrogen, as well as smaller quantities of sulphur. They all closely resemble in character the animal substance called albumen, or white of egg—hence they are called albuminous compounds, or albuminoids, and, from the fact of their being the more valuable principle of food, or the portion of it that supplies animals with the materials of which their blood, flesh, and structure are made, these compounds derive their more common name of flesh-forming principles. The names of these compounds are: vegetable albumen, legumin or vegetable casein, and gluten. The old method of calculating the total nitrogen of vegetable products into albuminoids has been found to require modification, for although in this way we obtain the "nitrogenous substances", these are not all albuminoids. The difference made by this fact is in some cases considerable, while in others, although perceptible, it is not wide; hence, useful as the relative amounts of their albuminoid and non-albuminoid nitrogen would become under certain circumstances, for ordinary commercial purposes, as in the analysis of cakes in which the proportion of the latter form is not large, any alteration in methods of determination is perhaps hardly desirable, as much confusion would be likely to arise.

When wheaten flour is moistened and made into a dough, and afterwards washed and kneaded in a stream of water, the starch, that forms a large proportion of flour, is separated and carried away, while an elastic, stringy mass remains. This is gluten, which may be accepted as a good example of all the albuminous compounds. Vegetable albumen is found in the juice of cabbage and other produce, and resembles the white of egg. Legumin is a peculiar compound, found in pease, beans, clover, and other leguminous plants, and is closely allied to the casein of milk, which, when separated, and further treated, forms cheese. All these compounds, which resemble one another very closely, and possess several properties in common, may be regarded as equally valuable in the animal economy. For this reason some chemists formerly considered them to be derived from one primary source which they called protein. Hence another name by which these bodies are known—protein compounds.

We annex a table showing the proportions of these substances in several kinds of vegetable produce :—

APPROXIMATE PROPORTION OF NITROGENOUS SUBSTANCES AND WATER IN FOOD.

	In one hundred parts.	
Wheaten bread	6	45
Wheat (whole grain)	12	12
Bran (outer and inner skins)	14	13
Fine flour	10	14
Oatmeal	13	14
Beans	25	12
Potatoes	2	75
Cabbage	1.5	86
Turnips	1.1	90
Carrots	1.4	87

In the bodies of animals, substances corresponding to each of these vegetable principles are found : they are called fibrine, albumen, casein, etc. For a long time these substances were regarded as peculiar animal products—combinations exclusively found in the animal system ; but such is not the case. It is now known that animals receive these principles ready formed in their food, and that they are in all cases prepared in the first instance by plants. In the case of herbivorous animals, or vegetable-feeders, the class to which most of our domestic animals belong, these compounds are extracted from the food by digestion and other processes, and conveyed to the blood.

The numerous products peculiar to the bodies of animals —as gelatine—the substance of skin, tendons, the organic portion of bones, etc. ; bile—the chief agent in the process of digestion ; and other animal substances, are all formed from the breaking up or separation into simpler compounds of the primary combinations supplied by vegetables. In the case of carnivorous animals several of these compounds are simply transferred from the flesh of the animals consumed as food to the blood of the consumer. Hence the process of digestion and assimilation is in this class of animals comparatively simple.

Since it is from these nitrogenous materials that the bodies of animals are built up and strengthened, it follows that the nutritive value of food, as far as its power of forming flesh is concerned, depends on the amount of such substances it contains—provided, of course, they exist in a condition that will admit of appropriation by the digestive organs of the animal receiving the food. In the human system, the most nourishing kind of food is generally well-cooked meat, or the flesh of animals in a state that will admit of ready digestion. This contains all the nutritive principles, as well as the respiratory material, in the shape of fat, in a concentrated, compact form ; and in this state food is more easily assimilated than when supplied in the shape of a bulky vegetable article of consumption.

As it is exclusively from the albuminous materials that the muscles and tissues, wasted by exertion and exercise, can be renovated and strengthened, it follows that a proper proportion of these substances must be present in every satisfactory diet, although, as we have seen, it is unnecessary to supply them as a means of enabling an animal to perform a full share of accustomed work, the more abundant carbohydrates, starch, sugar, etc., being thoroughly fitted for this purpose. At one time highly nitrogenous food was considered essential if hard work had to be accomplished ; experiment, however, seems to have proved that, although they may be used in this way, the facts now stated are true, hence a great consideration is evidently to provide sufficiently digestible food, for unless this can be ensured the capabilities of our animals must suffer and their stamina become impaired.

With young growing animals the case is very different, for a rapid increase of tissue must be provided for, wherefore it is essential to appoint for their use food rich in albuminoids. The animal body may in many respects be aptly compared to a machine, but we must not push this analogy too far, because individual constitution, likes and dislikes, etc., form very important considerations, on which account we must not expect that because so much fuel, otherwise food, is supplied, an unvarying mechanical result will be obtained.

Again, in the case of animals whose system is exhausted by the production of any particular secretion—as, for instance, in milch-cows—the food supplied must contain sufficient nitrogenous matter to furnish material for milk, in addition to that required by the ordinary waste of the body.

At the same time it must be remembered that although the more valuable nitrogenous or flesh-forming principles are able to support the various functions of animal life to a far greater extent than any other constituents of food, it is wasteful policy to use them when unnecessary, and doubtless if the amount provided is very excessive harm will follow. To illustrate that too much of a good thing is as undesirable in this matter as in all others, we may mention that gluten, the albuminoid of flour, when separated from the accompanying starch, etc., is found to possess a very indigestible character. A due mixture of the two sorts of compounds is the kind of food intended by Nature to support the health and strength of animals; and for this reason we cannot expect that a departure from her intentions can be persisted in for any length of time without serious derangement following.

STRUCTURE OF PLANTS.

Having described the products of vegetable life that take part in the nourishment of animals, let us now inquire into their production, and endeavour to ascertain how they are formed in the organism of the plant from the materials at its disposal. These, as we already know, are the constituents of the soil, of water, and of the atmosphere.

It will be necessary, first, to briefly consider the general structure of plants, as described by vegetable physiologists. Plants essentially consist of the root, stem, and leaves. The roots and fibres ramify in every direction in the soil, as the branches and leaves do in the air : the stem connects these two systems of organs. The substance of a plant—the greater part of its roots, stems, and leaves—consists of minute tubes or pipes for carrying the sap to every part of the structure. The stem is thus an arrangement of parallel tubes, some of which convey the sap from the roots to the leaves, others return the sap from the leaves back again towards the root. The extremities of the roots terminate in soft spongy organs, full of minute pores or openings, which are too small to allow of anything but liquids or gases passing through them: consequently solid matter cannot enter otherwise than in solution.

Through these pores, at the extremities of the roots, water and the substances dissolved in it are constantly absorbed, and conveyed through the inner portion of the stem to the leaves, where, by numberless small vessels, it is spread out over a large surface to the action of the air and light. Here the chemical changes take place that give rise to the production of the organic compounds above described. The sap containing these manufactured materials next passes downwards by the outer layer of tubes, or that which in trees forms the inner bark, and deposits the materials prepared in the leaf in the various organs of the plant.

Thus the leaf is the most important part of the whole plant, the organ more directly concerned in the production of the different kinds of organic principles. The surface of the leaf is covered by a multitude of pores or openings. Through these pores gases are constantly passing ; carbonic acid gas of the air is absorbed; water in the shape of vapour is evaporating. It is chiefly this evaporation of water from the leaf that gives rise to the circulating motion of the sap.

The water constantly evaporating from the surfaces of the leaves of plants, is supplied through their roots and stems from the moist soil. If this evaporation from the leaves is more rapid than can be supplied by the roots, the leaves droop—an effect constantly seen during the hottest parts of a summer's day. The same thing takes place when a plant is separated from its root, and this the more rapidly as the surrounding air is warm and dry. We avail ourselves of this circumstance when hoeing weeds during the hot sunshine: the weeds, when deprived of their roots, or removed from the moist soil, quickly wither and perish. Again, a flower plucked from its stem soon droops and loses its beauty, from this loss of water; but if we place its stem in water, some is taken up, and supplies the evaporation from the flower; so that its freshness is preserved for a much longer period.

The water that is thus constantly passing up through the stems of plants will, of course, carry with it the substances it holds in solution; and since these substances cannot evaporate with the water, they will be left behind in the organs of the plant: in this way the mineral food of plants is supplied. Every solid found in the plant must have entered in this manner through openings at the extremities of the roots, being, as before stated, too small to allow of the passage of any insoluble particles, however small they may be. But amongst the mineral or ash constituents of plants before enumerated, it will be noticed that several of them are insoluble in water; for instance, phosphate of lime, silica, etc. How, it may be asked, do these substances find their way into the plant? In addition to the action of the carbon dioxide present in soils, this is explained by the fact that roots of plants are able, by means of the acid sap they contain, to attack these insoluble compounds rendering them soluble, when they are conveyed throughout the substance of the plant in the same way as salts originally present in the soil in a soluble form. When we consider the vast importance of phosphoric acid and other materials of a like character to plant-life and their normal condition in our soils, we see how much depends upon a matter apparently so trifling as the sap of the roots possessing acid properties: the greater part of the ash constituents of plants appear to enter through the newly formed tips of the fine rootlets.

The organic portion of plants consists, as we have seen, of carbon, hydrogen, oxygen, and nitrogen. We will now consider the sources from which they derive these materials. The greater portion of their bulk—the carbon—is derived from the carbonic acid gas of the air, while, with certain slight exceptions, the rest of their substance is obtained from the soil. As before hinted, plants absorb this gas by their leaves from the air, as well as by their roots when dissolved in water, although this latter quantity is probably small. From whichever source derived, on exposure to the sunlight in the organs of the leaf, this gas is decomposed, and separated into free oxygen and carbon; the latter substance is retained, and by the same agency combined with the water also present, and formed into various non-nitrogenous compounds. All these compounds may be regarded as combinations of carbon with water, the oxygen and hydrogen contained in them being generally present in the proportions in which they exist in water. Thus from water plants obtain the oxygen and hydrogen, which with carbon are the only materials they require to produce all the non-nitrogenous or starchy compounds. This decomposition of carbonic acid, and its subsequent combination with the elements of water in the organs of the leaves of plants, is effected in a mysterious manner by the agency of sunlight, of which no satisfactory explanation has yet been found; it is, however, known that, generally speaking, the presence of chlorophyll or green colouring-matter is essential to bring about this change, although a remarkable exception to the rule has apparently been found in the organism producing nitrification. An idea of the amount of carbonic acid decomposed by plants is given in the following statements, to be found in the late Professor Bloxam's *Chemistry*, which will doubtless prove interesting. The oleander leaf was found to decompose on an average in sunlight about 67.5 cubic inches of carbonic acid to about every 11 square feet of leaf-surface per hour; but in the dark the same surface emitted about 4.25 cubic inches of carbonic acid gas per hour. The last remark is due to the fact that plants when in darkness do not decompose carbonic acid, hence no oxygen is evolved, and a process of oxidation whereby carbonic acid is produced becomes evident; this is always going on only as the action brought about by chlorophyll is the greatest, the secondary one can only be observed upon its cessation. We infer this method of obtaining carbon to depend upon the sun, because, as we have seen, it is known that plants can only perform this operation by daylight, and vigorously only during direct sunshine; but of the manner in which the light acts in breaking up these powerful combinations we are only able to form conjectures, or suggest probable partial explanations; and this matter becomes increasingly mysterious when we learn that the more complicated albuminous or flesh-forming principles are formed in the same manner by the agency of light. In these compounds, as we have seen, nitrogen and sulphur are present, in addition to the carbon, hydrogen, and oxygen of the simpler heat-giving compounds. The two former of these materials are obtained by the plant respectively from nitric acid and ammonia, and sulphuric acid; so that each of these powerful mineral combinations has to be decomposed; and their constituents, with those of carbonic acid and water, rearranged in complex groups, to form the gluten, casein, and other nitrogenous principles of food. When we learn that these marvellous transformations are effected by the agency of sunlight, we perceive how much we are indebted for our health, happiness, and even existence, to the glorious sunshine.

The nitrogen required by plants for the production of their more valuable albuminous principles is obtained either from ammonia, supplied by some of the means enumerated while speaking of the atmosphere, or from nitric acid, or some other form of combined nitrogen.

We shall understand that for reasons already given the nitrogen made use of by plants is mostly in the form of a salt of nitric acid.

The question naturally occurs to us: Why do not plants obtain the nitrogen they require from the free nitrogen of the atmosphere? It is because plants, notwithstanding the wonderful synthetical power, or the ability of putting together, they possess, are not able by direct means to overcome the natural disinclination of nitrogen, in a free state, to enter into combination with other bodies. The results of modern research appear to prove that leguminous plants are able to use free nitrogen through an indirect agency, which we shall explain more fully when considering crops of this order; the evidence we possess as to a similar utilisation of atmospheric nitrogen by other groups of plants hardly appears to support such a view. Why plants should be unable to avail themselves freely of this abundant supply of nitrogen, we cannot surmise; we only know that it is so, and may satisfy ourselves that it has been so arranged for a wise purpose.

To some extent we can imagine the different state of things that would exist in the absence of this arrangement. Nitrogen in an assimilable form, apart from its connection with the albuminous or flesh-forming principles of plants, exercises a stimulating effect on their entire organism, helping them to digest or appropriate the other kinds of organic and mineral food required for their development. For this purpose a small quantity of nitrate and ammonia is provided for the use of plants by Nature. But if we supply them with a larger quantity of nitrogen in the shape of manure, we must also furnish the other kinds of food, especially the mineral food, at a proportionate rate. In this case the stimulative effect of nitrogenous compounds resolves itself into a more rapid growth or a higher stage of development, and in the case of some cultivated plants we are enabled by this means to get a larger crop than we should otherwise. If, on the contrary, the mineral food of plants is not present in quantity proportionate to the nitrogen supplied, a deformed growth results; the due proportion between the several organs of the plant is interfered with; the leaves attain a monstrous size at the expense of the root or of the seeds. This effect would probably follow an unlimited supply of available nitrogen. We may therefore assume this as a reason why the nitrogen of the air is endowed with properties that limit its appropriation in the vegetable economy. It is perhaps almost unnecessary to mention that leguminous plants, although possessing an exceptional source of nitrogen, must have a sufficient amount of phosphoric acid, potash, etc., to ensure their healthy development. We may observe in passing that the last-named material appears useful for increasing the proportion of leguminous vegetation on grass land.

Thus we perceive that plants have been appointed to prepare from simple inorganic compounds, as carbon dioxide, nitric acid, ammonia, water, phosphoric acid, etc., the complex materials required to nourish the bodies of animals. These manufactured products, if we may so term them, when received into the animal system, become, on the one hand, the fuel that, by its combustion, produces the requisite animal warmth and mechanical force, while others constitute the new material which is constantly needed to replace the loss sustained by their tissue.

We therefore observe that in the bodies of animals an action the reverse of that prevailing in plants takes place. The compounds received in the food commence a series of downward changes, resulting in the reconversion of their constituents into their normal and simpler combinations. The respiratory principles of the food—the materials above named as the animal fuel—are consumed in the lungs, and are at once returned to the atmosphere as carbonic acid gas and water, while the more complicated flesh-forming materials, after having performed their appointed office in strengthening and invigorating the animal frame, are in their turn expelled from the system in simpler combinations, which, by spontaneous changes, quickly return to the forms they occupied before being appropriated by the plants.

Thus we are shown how plants provide food for animals. Animals do the same for plants ; and in either case life is sustained by the operation. Both classes of beings are manifestly dependent on one another for existence.

CHAPTER VI.

VEGETABLE PRODUCE OF THE SOIL.

We have already glanced at the general economy of vegetable life and the chemistry of the elements of which all plants are composed. We have also briefly described the composition of the more common products of vegetable growth, or at least of those that belong to feeding-materials. It has been mentioned that the vegetable productions used as food for man and animals consist of mixtures of compounds called by chemists proximate principles, but which are better known by their familiar names of gluten, starch, sugar, woody fibre, etc. These compounds, as we have seen, vary considerably in their usefulness in the animal system ; and as their relative proportions also vary most widely in different kinds of produce, it becomes necessary to learn the proportion of these several compounds that occur in cultivated crops before we can form an idea of the value of these crops and their fitness for particular purposes. It is also necessary to inquire into the individual characters and habits of the various cultivated plants, the soils most suited to them, and the kinds of manures best calculated to promote their vigorous growth. We shall do this most conveniently by following the natural classification, which may be thus stated :—

Cereal crops	Wheat, barley, oats, rye, etc.
Root crops	Swedes, turnips, mangels, carrots, etc.
Leguminous crops.........	Pease, beans, vetches, sainfoin, etc.
Fodder crops	Grass, hay, clover, etc.

We will now proceed to consider the composition and general economy of each of these kinds of plants, beginning with the cereal or grain crops.

The plants comprised in this important division belong to the natural family of grasses. We may therefore regard wheat, oats, barley, etc., as superior and highly-cultivated grasses. The distinguishing character of these plants is the production of their seeds in regular bunches, or ears, at the end of a long, upright, hollow stem. The stems of these plants are remarkable for the large proportion of silica they contain ; for this reason these plants are sometimes called "silica plants". Silica was at one time thought essential to their growth, but recent experiments tend to prove that this is not so ; its occurrence in such large quantity is owing to their apparently having the power of decomposing certain silicates in the soil, making use of any plant-food with which the silica is combined, and excreting the latter as a relatively waste product.

The stiffness of straw would therefore seem not to be dependent upon this constituent, but rather, as stated by Dr. Gilbert, on the favourable development of its woody substance ; indeed, generally speaking, silica is less abundant in better grown and ripened crops than in those of a poorer character. The authority just referred to also mentions the interesting fact that a high percentage of this substance causes straw to become brittle and less valuable for manufacturing purposes. Although silica appears non-essential to the growth of this order of plants, there seems good reason to believe that its presence exerts a favourable influence upon the development of their grain. The power cereals appear to possess of separating the constituents of silicates is a matter of value to succeeding crops not having a similar ability, for upon the decomposition of their roots, stubble, etc., in the soil, useful materials are yielded in a generally available form. The composition of the stems of these plants is as follows :—

COMPOSITION OF STRAW.

	Oat.	Barley.	Wheat.
Moisture	13.70	15.20	13.33
Fatty matters	1.69	1 36	1 74
* Nitrogenous substances	3.75	3.43	2.93
Soluble carbonaceous principles ...	36.64	31.75	32.34
Woody fibre	39.80	43.60	45.45
Mineral matters	4.42	4.66	4.21
	100.00	100.00	100.00
* Containing nitrogen	.60	.54	.47

The value of straw as fodder is now becoming more recognized, for it is found to possess properties too useful, when judiciously employed, for feeding-purposes to allow what may almost be called its waste as litter, for which it is by no means so well fitted as certain other materials—a point we have had occasion to mention elsewhere. Very much is it to be desired that these facts may become more generally admitted and acted upon, for indeed the position of farmers is clearly such that every possible source of profit and benefit must be carefully looked after : a lesson, although a most disagreeable one to learn, which may render even the present prolonged depression of some value, for in years gone by there has apparently been some tendency to regard too lightly the smaller items of farm-produce. On steeping straw in water for some little time a considerable quantity of carbonaceous matter passes into solution ; upon evaporating this liquid to dryness the residue is found to consist for the most part of a dark coloured substance which is very hygroscopic, *i.e.*, speedily attracts moisture from the atmosphere, and soluble, but almost tasteless. It differs from sugar in not being sweet, from starch by being soluble, and from gum by not being adhesive. It is called extractive matter, for want of a better name, which for general purposes answers very well—doubtless it really consists of a mixture of several substances. For obvious reasons the straw of a crop will possess a superior nutritive value before maturity is reached.

The seeds of these plants are extremely rich in feeding-material : the seed of wheat is probably the most nutritive vegetable product. These seeds or grains consist of a white hard substance, inclosed in several shells or husks. When ripe, the grain easily separates from the outer sheath, which remains attached to the stem or straw. As brought to market by the farmer, the grain consists of the above white substance, inclosed in a scaly covering. The relative proportion of straw and grain produced by these plants is, of course, different in each species ; but apart from this regular variation, it also differs in the plants of one species grown under different circumstances, being influenced by climate, soil, mode of culture, manure employed, variety of seed, etc. These crops are greatly benefited by the application of soluble nitrogenous manures, as they seem unable to make use of the ordinary organic nitrogen of the soil, and the early date at which they cease active growth prevents them gaining the advantage of the natural formation of nitrates during the later summer and autumn months. For this reason also they of course bring about a gradual loss of soil nitrogen, the products of whose oxidation, instead of being utilised, may drain away to some extent ; hence we see a catch-crop after corn, grown before the rains of winter come on, will be of special value and importance, for it will greatly minimise the possibility of loss.

COMPOSITION OF THE GRAIN OF

	Wheat.	Barley.	Oats.
Moisture	12.25	14.65	13.31
* Albuminous compounds	11.54	10.84	11.85
Starch, sugar, and other carbonaceous matters	71.85	66.28	63.23
Woody fibre	2.61	5.48	8.91
Mineral matters	1.75	2.75	2.70
	100.00	100.00	100.00
* Containing nitrogen	1.86	1.73	1.89

The proportions of the more important mineral constituents of these crops are: Phosphoric acid and potash in wheat, about .8 and .52 per cent. respectively; barley, .97 and .42; oats, .67 and .40.

WHEAT.—We will now separately consider the more prominent characters of each of the above kinds of grain-crops, beginning with wheat. We must all agree in placing this at the head of all cultivated crops. It deserves such a distinction from the fact of its being the origin of our daily bread—the source from which the chief part of the food of millions of human beings is directly obtained. As the grain of wheat is an article in such demand, it necessarily becomes the most valuable product of the farm; for this reason the wheat-crop is usually—in this country at least even now in some districts—the primary object for which the land is cultivated, and nearly all other crops are subservient to this one.

It is the business of the miller to combine and convert the grain derived from various sources into flour, and in most cases to remove the bran or inner shell. The flour thus produced is of several qualities, depending not only on the kind of wheat from which it has been prepared, but also on the treatment it has received at the hands of the miller. Each kind of flour is called by some technical name, indicating its degree of strength and colour, or freedom from husk, etc. Into the details of the process we need not think of entering, as it is sufficient for our present purpose to understand merely the general composition of white flour, which may be thus stated:—

AVERAGE COMPOSITION OF

	Wheaten Flour.	Oatmeal.	Bran
Moisture	13.50	13.09	12.86
* Albuminous compounds ...	11.48	15.68	13.80
Carbonaceous principles ...	73.52	68.17	55.73
Woody fibre	0.68	1.89	11.50
Mineral matters	.82	1.17	6.11
	100.00	100.00	100.00
* Containing nitrogen	1.84	2.51	2.20

Of these constituents the gluten is by far the most valuable, and it is on the larger quantity of this substance present in wheaten flour (not identified in above analysis) that its superiority, compared with that of other grain, depends. It is the amount of this substance that chiefly determines the "strength" of the flour, and its fitness for making into bread; the nutritive value of flour is, therefore, mainly dependent on the proportion of gluten it contains. It will be remembered that gluten is one of the complex vegetable albuminoids which contain nitrogen with smaller quantities of sulphur, in addition to the oxygen, hydrogen, and carbon of the more abundant but simpler products of plant-life; its separation from flour by washing has also been described.

The bran or husk of wheat is also very rich in nourishing materials, particularly in the more valuable mineral constituents of food—the phosphoric acid, magnesia, and other bone-forming substances. By glancing at the preceding table we perceive that the bran of wheat is even richer in nourishing materials than the flour. For this reason, the meal of wheat consisting of the bran and flour together makes a more nutritious description of bread—at least, for persons whose digestion is vigorous—than white flour alone. Hence, the complete removal of bran from wheat meal is a refinement of manufacture that cannot always be considered an improvement, at least so far as the production of a nourishing food is concerned.

On learning the composition of wheat, and considering the large quantity of nutritive materials its seeds contain, we can no longer wonder that it should require for its growth a soil rich in fertilizing constituents, or that it should exert an exhaustive effect on the land; that due to some other crops is, however, greater. For this reason wheat thrives best on a strong land, *i.e.*, land naturally rich in mineral fertilizing materials, and requiring only working and tilling to yield these materials. On soils of this description—and to a less extent on lighter land—nitrogenous manures are found greatly to favour the growth of wheat. These manures supply the nitrogen requisite for the formation of the gluten of the grain, and at the same time stimulate the plants to seek a proportionate quantity of the other kinds of material they require.

BARLEY is subject to the same causes of variation in quality as those that affect the wheat-crop, as soil, season, mode of culture, etc. Barley is found to flourish best on light rich soils ; and although a heavier crop may be grown on strong land, the finer varieties are always grown on light soils. By a glance at the above table (page 150) we perceive that the constituents of the grain of barley are the same as those of wheat, the proportions of them only being different : we notice that the former contains less gluten and more starch, although a smaller total of useful carbo-hydrates. For this reason the meal of barley is unfitted for making bread ; at least, the bread made from it is "heavier", less porous and wholesome than that of wheat-flour. The chief application of barley is for the production of malt. It is particularly adapted for this purpose from the large amount of starch it contains. By the process of malting this starch is converted into sugar ; and, by drying, the sugar is preserved from further alteration of any kind. The early stages of malting consist in exciting a premature germination in the seeds of the barley. By sprinkling with water, and keeping them at a particular temperature, the seeds begin to sprout or germinate, and put forth the rudiment of a root. The process is now arrested by drying. By this treatment we imitate the natural germination of the seeds in the ground. In both cases the chemical changes in the seed are the same, and may be described as follows. It would seem that a portion of the gluten or albumen, etc., first undergoes modification, being apparently converted into a substance called diastase; this diastase may be regarded as a natural yeast or ferment, which communicates the tendency to alteration to the starch also present in the grain. The starch is now transformed by a simple change into sugar, which is provided for the support of the infant plant. A beautiful natural arrangement may be traced in this series of changes that take place during germination. In the first stages of the existence of the embryo plant some kind of food must be provided to support it until it is able to collect supplies for itself from the surrounding soil. The food best suited for this purpose is found in sugar; but as this, if provided in the ripe seed, would quickly undergo spontaneous changes, and soon disappear, the materials only of sugar are provided, in the shape of starch. This substance is far more permanent than sugar, being insoluble in water, and less liable to change. At the time the immature plant shows symptoms of vitality, a substance is produced whose peculiar property is its capability of rendering the store of food available. Thus sugar is formed only at the time it is required, and the loss that would follow its formation at an earlier period prevented. The reserve material intended as food for the young plant exists in some seeds—linseed, for example—in the shape of oil or fat; the process of germination is in all cases, however, very similar to that described above. The embryo derives its nitrogen from the albuminoids.

Some authorities consider malt a useful article of diet for stock, and recommend it as a good means of using second-class barleys; certainly the material known as malt-cake is a useful article of food.

In this connection we may perhaps mention that sugar in a separate form does not seem to possess sufficient value as food to warrant farmers purchasing it directly, although any objection is only one of price. It is noteworthy that large quantities of this material are present in carob beans.

Oats contain the same materials as wheat and barley, but somewhat differently arranged. The composition of this grain may be judged of by the foregoing analysis. It is a crop well adapted for cool climates, as it ripens better than wheat under such circumstances; and much of a farmer's success must depend upon modifying his procedure to the requirements of his district, the climate being no mean factor in his calculations.

Leguminous Crops, as peas, beans, vetches, sainfoin, clover, etc., all partake of the character of the pea, which may be accepted as the type of this order. The prevailing mineral constituent of these plants is lime: for this reason they are sometimes called "lime plants". As we might for this reason expect, these plants flourish most luxuriantly on lime soils, and are cultivated most successfully in limestone districts. For the same reason, the addition of lime to soils containing but little of this substance greatly favours the growth of these crops. Another mineral constituent required by these plants is sulphur; hence the addition of some combination of sulphur is generally attended with benefit to a crop of this description. A substance well fitted for this purpose is gypsum, or plaster-of-Paris. This compound, as already noticed, contains sulphuric acid and lime, and on this account may be regarded as a special manure for leguminous plants.

Many of these crops are cultivated as much for their stems and leaves as for their seeds. Their employment in a green state as fodder for cattle will be considered amongst other fodder crops. For the present we need only direct our attention to the properties of their seeds.

The seeds of beans, peas, and other plants of this group are highly nourishing feeding-materials. Like the grain of the corn-plant, this superior nutritive value is due to the large proportion of nitrogenous or flesh-forming materials they contain. In these seeds the nitrogenous matter is not gluten, as in the case of grain, but consists of a peculiar vegetable principle called legumin, or vegetable casein. This latter name is given to this compound from the fact of its resembling in its chemical properties the casein or curd of milk. We shall better understand the composition of the plants by glancing at the following table:—

COMPOSITION OF PEAS, BEANS, AND LENTILS.

	Peas.	Field-beans.	Lentils.
Moisture	14.12	14.81	12.14
* Legumin and other nitrogenous substances	23.43	24.72	24.32
Carbonaceous principles	52 05	46.94	52.05
Woody fibre	7.89	10.12	8.93
Mineral matters	2.51	3.41	2.56
	100.00	100.00	100.00
* Containing nitrogen	3.75	3.95	3.89

By comparing the analyses of this class of plants with those of wheat, etc., we shall observe the nitrogenous substances in the former to be as nearly as possible double the amount contained in the latter. For a long while it was a greatly contested point as to what was the origin of this large quantity of nitrogen; for, so far from the soil being impoverished by their growth, the *débris* of such a crop would often render the land richer in this important element than before. It was likewise found that nitrogenous manures had but little effect upon them; careful experiments had also been made to discover whether the free nitrogen of the atmosphere is assimilated by plants. With most crops it appeared evident that no such source of nourishment was available, while in the case of the leguminous order a doubt remained, the results obtained not being decisive. Recent investigation, however, appears to have conclusively proved that, by the indirect means of certain organisms present in the tubercles or nodules found on their roots, these plants are able to make use of free nitrogen. This indirect method of obtaining nourishment through the agency of what is called symbiotic life, appears not to be confined to these crops, but is even found to exist with various trees, among which is the well-known oak. The reason this source of nitrogen had not been discovered by the experiments of former years was that the precautions taken included not only the exclusion of combined nitrogen but also sterilization of the soil; which is to say, these necessary organisms were not present, hence negative results followed: for it must be most clearly understood the plants themselves seem quite incapable of fixing nitrogen. The minute organisms referred to above, of which little is yet known, would appear to accomplish this, while the roots of the plants feed upon the resulting products. We must also bear in mind that leguminous crops are not entirely dependent upon this means of obtaining nitrogen, but also procure it from the soil through the usual channels, those possessing deep roots searching the subsoil for supplies of this and other requisite nutriment. A very interesting point in connection with this subject is that it appears necessary for a particular organism to be present to produce the effect upon a particular plant; for instance, we might refer to the lupine organism, without which this plant apparently could not assimilate free nitrogen. Uncertainty would still seem to prevail as to the conditions under which a greater or less proportion of the total nitrogen of a crop is obtained in this way or from the nitrogenous compounds of the soil. Another most important, as well as highly interesting, question suggests itself, viz., whether the exhaustion of any particular organism has an influence upon the well-known sickness, as it is called, that attacks soils after producing these crops for any length of time. These and other points require elucidation, but, in the meantime, it is a matter calling for great satisfaction from both the purely scientific and practical standpoints: to believe that an explanation of this mysterious increase of nitrogen is now forthcoming, for without doubt the addition of this element to his land by the cultivation of these crops is one of the most valuable resources at the farmer's disposal ; indeed, he has been well aware of this for many years, but with a knowledge of the reason he will be able to work with greatly increased confidence. Evidence of the utilization of nitrogen from this source by other families of plants would appear but slight, if any, although there seems good reason to think those growing near a leguminous crop share to some extent the benefits they enjoy.

ROOT CROPS, as swedes, turnips, mangels, carrots, etc., are cultivated solely for their roots, or rather bulbs. The habit of these plants is to gather from the soil, during the earlier stages of their growth, a larger quantity of nourishing materials than they require for present use. This extra quantity of food they store up and accumulate in their bulbs, and it is afterwards disposed of in maturing their seeds during the later period of their development. Thus we learn that during one period of the growth of these plants the bulbs continue to increase in size and to become richer in feeding-materials up to a certain time, when a change in the reverse direction takes place, and the bulb is called upon to supply materials for the sustenance of the other organs. Hence we see the necessity of gathering the roots or bulbs when fully matured in order to obtain the maximum quantity of feeding-materials. If we leave them longer than this, the amount of woody substance in the root increases, and it therefore becomes less nourishing ; and when the plants are allowed to perfect their seeds, the bulbs are found after the operation to consist chiefly of woody matter, everything they contained in any way useful as animal food having been extracted for supplying material in the production of the seeds.

Root crops are generally more difficult to raise, and require more care for their successful cultivation, than the crops before described. This is because these plants are more subject to natural casualties, sooner affected by disease, blight, and unfavourable seasons, than many other crops. For this reason too much reliance should not be placed upon them, and, indeed, it would appear that certain crops of a different order are tending in some districts to partially replace these. A striking instance of the risk attending the growth of turnips was supplied during the frost of last winter, when many farmers were caught napping in this matter, for, instead of being stored and collected in clamps, these roots, in too many cases, were still exposed in the fields, where they were firmly fixed, and upon the thaw setting in soon became rotten. We need hardly say here that we cannot consider them when in this condition at all desirable food for stock. Malt dust has been mentioned as a useful material to counteract any ill-effects of these frozen roots when their use cannot be avoided. We may perhaps add a word in this place on the value of silage in such seasons, for it is found very easy to work, and possesses a comparatively high temperature—considerations of no little moment under these circumstances. We enter more fully into this subject later on, but make this passing reference, as from time to time remarks appear which imply that in some neighbourhoods the practice after a short trial has been allowed to drop. This is unfortunate, for, possessing so many advantages as it does, we would strongly advise farmers not to be discouraged by a few failures, but try once more; especially do we appeal to clay-land farmers, to whom the process would appear particularly valuable. Root crops flourish best on light soils that are neither too wet nor too dry: the roots are rendered watery and hollow by too much damp, and are equally susceptible of injury by drought. Hence the produce of this crop is often more affected by the season than by any circumstances within our control. We have before remarked that the turnip-plant is unable to gather its food from any portion of the soil remote from the seat of its growth. In all the plants of this group the roots are less developed and fewer in number than those of most other kinds of cultivated plants; for this reason we must supply them with material for their increase in a form that will admit of its ready appropriation.

Since the root crop, of all others in the series of a rotation, is least able to collect its food from the substance of the soil, we generally supply the manure to this crop, and give these plants the benefit of first choice, so that they help themselves to all they care to possess, while the remnants are left for the following crops. The manure usually applied to root crops is well-rotted farmyard manure and superphosphate. The latter substance is frequently employed alone. But in this case the farmyard manure must be added previously, or at some other period of the rotation.

Superphosphate of lime is particularly adapted for promoting the growth of root crops, especially swedes and turnips. On mangels, in addition to phosphates, nitrogenous manures are generally advantageous. It acts chiefly by supplying these plants with abundance of phosphoric acid at the period they seem to require it most, viz., during the very early stages of their growth; and, as before noticed, an additional advantage is secured by the use of superphosphate, from the vigour it imparts to the young plants, which, thus strengthened, are better able to resist the attacks of the turnip-fly. Besides phosphoric acid, in a form that can readily be assimilated, these plants require the alkali potash in some form. Hence, in soils naturally deficient in this material, the addition of kainite or other source of potash may be expected to benefit these crops. Mangels particularly require a large quantity of alkaline matter; so that the addition of common salt to the other manures applied to this crop will in most cases be found to increase the produce.

The successful cultivation of the root crop, particularly swedes and turnips, requires more than ordinary care and experience; and the condition of this crop on a farm displays as much as anything else the skill and ability of the farmer. Apart from the natural casualties to which this crop is peculiarly liable, its growth can be regulated to a great extent by proper care and attention; for much depends on the time of sowing and the state of the weather and of the ground at this period: an opportunity lost then will affect the future produce. Again, a great deal depends on the quantity and quality of manure employed, or on the proper regulation of the manure to the capability of the soil. A soil of a certain quality, depending on its chemical constitution and mechanical condition, will produce its maximum produce of roots by the addition of a certain quantity only of manure. If this amount is exceeded, the excess, instead of adding to the produce, as might be expected, diminishes it, by exciting an undue development of leaves at the expense of the bulb; in other words, the higher the state of culture of a soil the more manure may be used upon it, with the expectation of this manure producing a corresponding amount of produce.

Root crops are almost exclusively cultivated for feeding cattle, and generally supplying the stock of the farm during the winter when no green food is to be had. We may therefore regard this produce as a portion of the raw material of mutton and beef; at the same time it supplies material for the manufacture of manure. Before proceeding any further, let us make ourselves acquainted with the composition of these crops.

AVERAGE COMPOSITION OF ROOTS.

	White Turnips.	Swedes.	Mangels.	Potatoes.
Water	90 43	89 46	87 78	75 00
*Nitrogenous substances ...	1.04	1.34	1.54	2 32
Pectin, sugar, and other carbonaceous principles	6.78	7.35	8.54	19 69
Woody fibre	1.12	1 23	1.18	1.86
Mineral matter	.63	.62	.96	1.13
	100.00	100 00	100.00	100.00
Containing nitrogen ...	.16	.21	.24	.37

We are astonished at the enormous quantity of water in these roots ; in round numbers, nine-tenths of the produce consists of water, or, in the case of swedes, 100 lbs. of roots, in the state they are usually stored, contain but 11 lbs. of dry matter. On becoming acquainted with this fact, we can no longer wonder at the large quantity of such food consumed by cattle : the animals must eat 100 lbs. of swedes to get 11 lbs. of real food. The dry substance of these roots consists of feeding-materials that are soluble in water, as sugar, a large proportion of pectin or jelly-like substance, as well as the more valuable flesh-forming materials. It also contains a smaller quantity of insoluble matters, all of which, with the exception of the matured woody fibre, are digestible and nutritious. We also notice that of the three above-named roots the swede contains less water and more feeding-material than the white turnip ; moreover, the dry substance of this root contains a larger proportion of flesh-forming material than that of the latter. Hence we can account for the well-known superiority of the swede as a general feeding-material. Mangels are distinguished by the large quantity of sugar they contain. Sugar beets are still richer in this compound, and form a valuable food. Attempts have been made from time to time to grow these roots in this country for the manufacture of sugar, but have not hitherto met with much success. It will be remembered that sugar is one of the substances capable of producing fat in the animal system : thus the superiority of these roots for fattening beasts is explained.

It must be clearly understood that the value of these feeding-materials is very different from grain, cakes, etc. Of course it is very evident the useful constituents are in a considerably more dilute condition. This, however, is not all, for the seeds are the most perfect production of a plant, while these bulbs are, as we have seen, merely storehouses of food for the later stages of growth, whose nature will vary greatly according to the fertility of the soil, size of root, etc. But a large proportion will always be in a kind of transition stage of formation ; thus, much of the nitrogen does not exist as albuminoids, and is, therefore, unable to build up tissue. For this reason it is important to know, when roots are analysed, the proportion of nitrogen present in the more valuable form, while for the reason already given, page 136, such knowledge is not generally necessary in the case of cakes, etc.

Potatoes form a valuable crop, and well deserve the farmer's careful attention. They are, however, very liable to disease, which is greatly promoted by continuous wet weather. It is also found to attack most those grown by highly nitrogenous manures ; hence much discretion is needed in their cultivation, for even with sufficient mineral constituents—amongst which potash is of special value to this crop—a satisfactory yield cannot be obtained without a full supply of available nitrogen. The disease appears to be a fungus, which develops at the expense of the tubers, starch being destroyed and sugar formed. A remark or two may be made respecting the mode of cooking this valuable food, of whose nitrogen a larger proportion has been found to exist in the albuminoid form than in roots proper, but this is largely in a soluble condition ; therefore, upon placing them in water after peeling, etc., a considerable loss of important constituents must occur : for which reason, steaming, boiling, or, better, baking in their skins or jackets, is greatly to be preferred.

A previous reference has been made to the experiments undertaken for the purpose of ascertaining the value of cupric sulphate (sulphate of copper) and lime as a preventive of disease in this crop, and it is most sincerely to be hoped a favourable result will be obtained ; at the same time, doubtless, a great deal may be done by a wise choice of seed, care being taken to avoid that inbreeding which is so often a source of weakness, rendering the produce quite unfitted to withstand an attack, of which abundant proof has lately been supplied in Ireland.

Fodder Crops.

Under this head we include grass and hay, clover, sainfoin, Italian rye grass, and green food, as rape, mustard, etc.; also ensilage.

Grass and Hay.—The green herbage that in most places covers the soil in a state of nature consists, for the greater part, of different sorts of grasses more or less adapted for affording sustenance to herbivorous animals. We may therefore regard grass as the food provided by Nature for the support of this class of animals ; and as in all cases her arrangements are complete and perfect, we cannot be surprised that grass and hay, when of best quality, should constitute fodder upon which all kinds of cattle thrive.

Could we obtain at an economical rate enough of these materials to feed our cattle, no other description of fodder would be requisite. But as this is seldom the case, and as by the present system of agriculture it is more profitable to cultivate other kinds of fodder-crops, grass and hay, in most cases, form but a small portion of the fodder supplied to stock. At the same time, grass and hay are justly esteemed as choice articles of cattle-food. The latter especially, when it can be advantageously obtained, is, in most cases, to be preferred to other sorts of winter fodder ; and for this reason hay is generally preserved as a material to be sparingly and judiciously used at critical periods.

Two varieties of grass and hay are usually met with : 1. That produced in permanent meadows, where the soil is exclusively set apart for the growth of this produce. 2. That raised from artificial or temporary meadows, periodically cultivated in a rotation of crops. In both cases the grass is either consumed in a green state by cattle put to graze on the land, or is preserved by drying, in the shape of hay, or otherwise dealt with. The tendency in recent years is to lay far more land down to grass. This is to be regretted as a sign of the decadence of wheat-growing, although the weather of the last few seasons, apart from economical considerations, has been such as to favour the view that our climate is better adapted to grazing purposes than to raising corn.

The produce of temporary pastures is generally considered less valuable as feeding-material than the grass or hay of permanent meadows ; while the former is often more abundant and profitable, the latter is sweeter and finer, and holds the first rank in the list of fodder-crops.

The quality of permanent pastures probably varies to a greater extent than any other kind of cultivated land. While some districts are remarkable for the richness and luxuriance of their grass-land, and have become notorious for the superior quality and abundance of every sort of produce raised from this kind of land, in others the natural pasture is so poor and scanty as to be hardly capable of affording a subsistence to the animals kept upon it. These differences in the productiveness of pastures are due to a variety of circumstances besides the more immediate one of difference of soil : the age of the pasture—the treatment it has undergone—the species of grasses growing upon it, and especially the state of the soil in regard to water. All these reasons may take part in altering the natural capabilities of the land. Amongst the causes that lessen the productiveness of pasture-land, the presence of stagnant water holds a prominent place. Land that, from imperfect drainage, contains stagnant water is found to encourage the growth of coarse, sour species of grass, deficient in every useful quality ; and although the soil may contain the elements of fertility, yet in the presence of this water these kinds of grasses will prevail. By draining such land, the inferior grasses will slowly disappear, and give place to a sweet, wholesome herbage. This desirable change may often be hastened by the addition of the seeds of the grasses we wish to raise, as well as the manures best fitted for affording them nourishment. It is only when stagnant that water exerts this injurious effect on grass-land. Provided means exist for its removal when necessary, the flooding of meadow-land by water is, in most cases, followed by an increase both in the quality and quantity of the grass. Hence, whenever practicable, the practice of irrigation is eagerly resorted to as a means of increasing the produce of land so cropped. The properties of water, on which its usefulness in this operation depends, have been already described.

The composition of grass and hay may thus be represented :—

AVERAGE COMPOSITION OF NATURAL GRASSES.

	Grass.	Meadow Hay.
Water	76.52	16.66
Fatty matters, chlorophyll, etc.... ...	1.40	5.01
* Nitrogenous substances	2.25	8.08
Sugar, gum, cellular tissue, etc.... ...	12.68	34.86
Fibre	4.97	27.64
Mineral matters	2.18	7.75
	100.00	100.00
* Containing nitrogen	.36	1.30

The above tables may be considered to represent the average composition of grass and hay. It will be seen that in fresh grass the quantity of water is very large, although less than in turnips, swedes, etc. The dry substance consists for the greater part of respiratory or fat-producing substances, and indigestible woody fibre. This latter substance, being almost useless in the animal system, must not be taken into account in estimating the value of feeding-materials. Amongst the former substances we find fatty or oily matter, a constituent that materially adds to the value of grass and hay as feeding-materials ; there is also a considerable portion of the more valuable albuminoids or flesh-producing compounds. The ash or mineral constituents are also large in comparison with other fodder-crops.

In hay we find the same materials in greater proportion. As the hay contains much less water, it is, of course, richer, weight for weight, than grass. The qualities of this product depend very much on the age of the grass at the time of cutting, as well as on the treatment it has undergone during its conversion into hay. It is well known that young grass is more nutritious than that which has passed maturity. This is explained by the fact that the quantity of indigestible woody fibre rapidly increases as the plants arrive at full growth. For this reason it is desirable to cut the grass intended for hay as early as possible, since a delay at this critical period may greatly reduce the nutritive value of the produce. The quality of hay is often deteriorated by prolonged wet weather and other circumstances over which the farmer has no control. In the case of damage by rain, the soluble matters are washed out, in some cases leaving little else than the woody fibre of the stems. Moreover, in these cases, the hay is always more or less injured by incipient decay.

The growth of the grasses tends to improve and enrich the surface-soil, and, as before hinted, is one of the means provided by Nature for the amelioration of nearly all crude or new soils. By the successive growth and decay of the plants composing the natural herbage—which sooner or later springs up whenever masses of earthy material are exposed to the weather—the upper layer of earth accumulates, and is slowly converted into a soil more or less capable of rewarding the labour and skill of the husbandman.

The production of a fertile soil from a barren surface of earth by the prolonged growth of grass is strikingly exemplified in the case of several of our finest pasture-lands, which often rest upon beds of clay, whose surfaces have by this means become covered with a rich, deep mould. The habits of the grasses on which this useful effect depends may, to some extent, be explained as follows: these plants are remarkable for the large quantity of roots they produce during their growth, and for their ability of collecting and retaining the fertilizing materials existing in the atmosphere. Any leguminous plants present have of course a special value in this respect, as some of their nourishment is derived from free nitrogen, which upon the decay of their roots, etc., is yielded as available plant-food ; doubtless, also, the benefit of having such desirable neighbours exerts an influence upon the grasses belonging to different orders of vegetation—a hint which will be understood by the remarks made when we were considering the leguminous crops. The mineral substances they require are supplied by the soil, as in the case of other kinds of plants ; but many of these grasses possess the power of seeking for the mineral food they require from great distances. They thus ransack the remoter portions of the soil, and convey its hidden treasures to the surface. The constant presence of a crop also greatly protects the land from loss of nitrogen through drainage, the nitrates being assimilated by the growing plants. On the decay of these plants, the materials they have collected from the air, etc., are left in the soil, which is thus made richer in organic matter, or humus, while, at the same time, the surface-soil is also enriched by the mineral fertilizing materials brought from lower sources. The humus and organic remains thus contributed to the soil by these plants, apart from their chemical effect on the growth of subsequent races of vegetation, materially improve its texture by loosening and separating the particles of earthy matter.

We shall easily understand that to annually remove grass as hay must be a very exhausting practice, hence an equivalent for the constituents lost must be provided either by animal or artificial manure—farmyard manure, and feeding animals on the land receiving additional food from external sources being the most satisfactory.

We avail ourselves of these useful properties of the grasses by introducing them as one of the series of crops of a rotation. By this means we not only obtain a crop of hay or a large quantity of the best sort of green fodder, but at the same time our land is greatly improved, and better fitted for the growth of the following wheat-crop. The roots, stems, and leaves of the grasses, on being buried in the soil, gradually decay, and supply the succeeding wheat-plants with all the materials they require for their growth in a highly acceptable form. The artificial or temporary meadows cultivated for this double purpose are generally formed by sowing several sorts of clovers and grasses with a corn-crop—generally barley. The grasses thus grow amongst the barley during the first year of their growth, and the following summer spring up and form a pasture, whose productiveness, of course, depends on the quality of the soil and the species of grasses sown.

The average composition of the commoner varieties of clover and other allied plants is as follows :—

AVERAGE COMPOSITION OF CLOVERS.

	Red Clover.	White Clover.	Yellow Clover.	Lucerne.	Sain-foin.	Vetches.
Water	80.64	83.65	77.57	73.41	77.32	81.38
*Nitrogenous substances	3.60	4.52	4.48	4.40	3.52	3.62
Carbonaceous principles	13.79	10.26	15.94	19.11	17.43	13.26
Mineral matter	1.97	1.57	2.01	3.08	1.73	1.74
	100.00	100.00	100.00	100.00	100.00	100.00
*Containing nitrogen	.57	.72	.71	.70	.56	.58

On comparing these results with those of the analyses of the natural grasses before quoted, we notice that while the general composition is much the same in both cases, the artificial grasses contain, on the whole, more water, and, at the same time, more albuminous or flesh-forming principles than the natural grasses. The produce of artificial meadows is subject to the same causes of variation as those described as affecting the hay and grass of permanent pastures ; and the remarks thereon offered apply with greater force to the present kind of produce, as pointed out under leguminous crops.

The produce of pastures, of whatever kind, is either cut down and gathered in the form of hay, or is consumed by feeding off with cattle. In the former case, where the greater part of the produce is directly carried away, the land, of course, loses more of its essential constituents than when the same produce is consumed on the spot and a considerable portion of it returned in the shape of manure. But even by this latter system the soil is often exhausted to a greater extent than we should at first imagine; since on feeding off with cattle, the amount of essential substances permanently retained in the bodies of the animals, and, consequently, the extent to which the soil is exhausted, depends on the kind and condition of the stock employed in the operation. If the animals employed for this purpose are full-grown, and in tolerable condition, nearly all the nitrogen and mineral matter existing in the fodder will be returned to the soil in their excrements ; and, so far as the mineral substances and nitrogen are concerned, the soil would be in nearly as good condition after the process as before, the only substance lost to the soil being that portion of its carbonaceous matter which has been converted into volatile products by the respiration of the animals, or that has been deposited in their tissues in the shape of fat. But in the case of animals that are lean or in bad condition, a portion of flesh-forming materials will also be permanently retained in their systems, to make up the increase of flesh consequent on their arrival at a better state of body. In the case of young or growing stock, the loss sustained by the soil under these circumstances is still greater, as, in addition to the carbonaceous and nitrogenous materials, the soil will also have been deprived of the phosphates or bone-material required for the enlargement of the bones of the growing animals. Again, a corresponding loss of material will follow the pasturing of land by milch-cows. The nitrogen and valuable mineral salts occurring so abundantly in milk will be formed at the expense of the soil bearing the pasture on which the cows feed. Thus we perceive that whenever grass-crops are fed off the land, the soil incurs a loss of fertilizing materials equivalent to the flesh, milk, or other animal produce formed through the instrumentality of the stock fed upon them. The same principles hold good with all other crops disposed of in a similar manner.

HAY OF CLOVER AND ARTIFICIAL GRASSES.

Moisture	16.50
*Nitrogenous substances	15.81
Carbonaceous principles	37.63
Woody fibre	22.47
Mineral matters	7.59
	100.00
*Containing nitrogen	2.53

The manures applied to grass-land should be of a mild, slow-acting description, and all ammoniacal manures should be applied only in small doses, and evenly distributed ; since anything like an overdose of ammonia tends to develop a coarse, inferior sort of herbage. We notice this in the tufts of coarse grass that always spring up when the droppings of the larger animals are suffered to lie in masses on the pasture where they have been deposited ; for the same reason, guano, unless much diluted by admixture with other substances, cannot be advantageously applied to grass-land, as it is apt to excite an excessive development of grass of a rank, inferior description.

Sainfoin has before been noticed as a crop especially adapted for cultivation on thin light soils resting on the porous limestone rocks. The usefulness of sainfoin in soils of this character depends on its habit of sending its roots to great distances into the fissures of the subjacent rock, and extracting from it the small quantities of mineral fertilizing matters it generally contains. The valuable materials thus collected are brought to the surface and deposited in the various organs of the plant. On the conversion of the plants into manure, by feeding off, ploughing in, or otherwise, the surface-soil is enriched by the addition of those substances brought up from the depths of the subsoil.

Green Rye is a crop that is held in some favour on account of the fine rich pasture it produces at a season when other kinds of grass are scarce. From the extraordinary rapidity of its growth, this species of grass gives a pasture in a very short time. It is mostly employed for supplying the ewes and lambs with wholesome food during the spring months. Recollecting the use to which it is applied, we cannot be surprised that this crop should have gained the character of being a very exhaustive one : it must necessarily be so, when, as is usually the case, it is pastured by young animals.

GREEN RAPE AND WHITE MUSTARD are both useful fodder crops ; the former is particularly worthy of notice, since, in addition to a considerable proportion of flesh-forming materials and the ordinary respiratory principles, it contains a larger proportion of oil or fatty matters than is found in most other green crops. This fact clearly explains the well-known fattening qualities of rape as a food for sheep. The value of green rape as a fodder-crop is highly estimated by some persons, who even recommend it to be occasionally cultivated in place of turnips, wherever the soil is good enough to admit of its vigorous growth. The merits of vetches are too well known to require comment.

Rye, rape, and mustard form excellent materials for catch-crops, the extended use of which is greatly to be desired, on account of the many benefits they confer upon the farmer.

CABBAGE AND KALE.—From the numerous useful qualities of these plants, they deserve to be more extensively cultivated as fodder-crops. We are glad to notice that latterly there has been some considerable awakening to their usefulness as food-supplies ; the great bulk of crop produced, in addition to its quality, certainly gives them a claim to our careful attention. The latter, especially, is much recommended by some authorities in place of roots. Kohl rabi belongs to this class of plants, and possesses certain advantages. From the fact that cabbage is richer in oil and nitrogenous matter than most other kinds of green food, and at the same time very succulent, its nutritive qualities are not to be wondered at. Cabbage is most valuable as a food for milch-cows : it increases the quantity and quality of the milk, and the butter made from it has not any unpleasant flavour. For other purposes, a more extended use of the plant is to be recommended.

The composition of this and some of the above-described crops is as follows :—

COMPOSITION OF

	Green Rye.	Green Rape.	Cabbage.
Water	75.42	87.05	89.42
Fatty matters	.89	.64	.58
* Nitrogenous substances	2.73	3.13	2.75
Carbonaceous principles, fibre, etc.	19.61	7.57	6.40
Mineral matters	1.35	1.61	.85
	100.00	100.00	100.00
* Containing nitrogen	.43	.50	.44

Ensilage.

This method of storing fodder appears to be of ancient origin; the practice remained dormant, however, for many years, and it was not until quite recently, comparatively speaking, that it commenced to hold a position of importance in British agriculture.

The principle of making silage is extremely simple, the raw material being merely collected together and pressure of some kind applied.

In practice there are several methods of carrying out the process : we have silos formed by digging pits in the earth and afterwards carefully lining them with cement ; others are built above-ground ; while a third class, being partly sunk and partly raised above the surface of the land, partakes of the characters of both the foregoing.

It is the custom in the most recent methods only to stack the fodder, treading down each layer and applying pressure in various ways, of which the following are examples : by a system of pulleys and wire ropes, or placing on the top any heavy materials at hand, one plan being to build a haystack above the silage; or the fresh portions of green crops as they are added are thoroughly compressed by means of a heavy roller. All these systems, when carefully carried out, will probably be found to yield satisfactory results, the main question to the producer being of course one of *£ s. d.*; and we all must agree that so long as he does not sacrifice the quality of the product, a farmer is acting most wisely when adopting the plan which in his hands proves most economical. It would appear desirable when forming a silage-stack to arrange for a continuous application of pressure as the bulk decreases.

Two varieties, known as sweet and sour silage, are produced by certain modifications in the details of preparation; thus, if pressure is applied to finely-cut fodder as soon as it is collected, the smallest amount of heating takes place and fermentation occurs, resulting in the formation of the sour variety. When circumstances are changed, however, the crop being accumulated slowly and pressure not applied until a temperature of 140° Fahrenheit is reached, we obtain sweet silage. It does not yet seem settled which of these two classes is to be preferred, but practical men by comparing notes might speedily throw some light upon the matter, and doubtless the investigation would prove most useful and interesting. The changes occurring in the formation of this material result in a loss of water and carbohydrates; the nitrogen, too, although not lost, at any rate to an appreciable extent, is apparently caused to assume a different form of combination. Undoubtedly it would be far more satisfactory if this were not the case, and the albuminoids remained unaltered. Notwithstanding this fact, however, the conversion of fodder into silage has so many advantages that it deserves to be far more generally adopted.

Of course it must not for a moment be supposed that hay either should or will be displaced, but in seasons when the weather is so wet or uncertain that to cut grass means running a serious risk of having the nourishing constituents washed away if it remains in the fields after cutting, while if allowed to stand it must become too old and of a woody character, there can evidently be no question that our wisest policy is to form an ensilage-stack, when we become independent of the weather, for it is possible to carry on this process with our grass in a wet state—a consideration of the highest importance to English farmers. Again, we are able in this way to store green fodder of far too succulent a character for making into hay ; coarse grass and even weeds of a non-poisonous character are useful, and may thus have during the winter and early spring months a supply of a class of food which is most urgently needed at that time, providing our stock with a change of diet, and, what is still more important, in the event of any misfortune happening to our turnips, we are able, if possessed of a store of good silage, to face the situation with but little anxiety, for, in addition to having a good feeding-value, farm animals have shown a considerable liking for it. On these grounds farmers would without a doubt be acting in their best interests were they always to preserve a certain proportion of their crops in this way, the amount naturally being greater in a wet season. The question also presents itself whether on lands not suitable for roots the effort to grow them should not be abandoned and crops for ensilage take their place.

AVERAGE COMPOSITION OF MEADOW-GRASS SILAGE.

Water	72.14
* Nitrogenous substances	3.01
Carbonaceous principles	11.90
Fibre	9.61
Acids, flavouring constituents, etc.	.83
Mineral matters	2.51
	100.00
* Containing nitrogen	.48

CHAPTER VII.

ANIMAL PRODUCE.

Having now made ourselves acquainted with the composition of the vegetable produce raised on the farm, either for being carried to market and sold, or for home consumption as feeding-material for the live stock of the farm, we must next consider the chemical principles involved in the conversion of this latter kind of produce, as grass, hay, roots, etc., into animal products, as beef, mutton, cheese, milk, etc. In order to understand the composition of these various animal substances, and how they are formed in the system from the vegetable compounds consumed as food, it is necessary to glance at the general principles of the animal economy.

The operations involved in the process of nutrition have for their object the transformation of inanimate or dead matter into living substance. Without entering into anything like a detailed description of these operations, we may briefly describe them as follows :—

The body of an animal resembles a machine, in so far that by every movement of its parts or organs a certain amount of substance is worn away or destroyed. In the case of a machine, this loss by wear and tear is incessant while the machine is in motion, and sooner or later results in its destruction ; but in the case of a living machine, as we may regard the bodies of animals, this loss of substance by exertion or wear is restored and replaced by new material, which is constantly provided for the purpose by the consumption of suitable food. Thus, in the animal system there are two operations constantly going forward—the destruction and removal of old or exhausted materials, and the renewal or building up of new substance in place of that worn away. In the young animal this latter process prevails ; and the quantity of new material being greater than that removed by exertion or exercise, every part of the system is strengthened and enlarged, and continues to increase in substance and bulk, until the animal attains full growth. These two operations being indispensable to the very existence of all descriptions of animals, it is clear that some means must exist, not only for supplying new material of every sort required to build up the several parts of their frame—as the bones, flesh, hoofs, etc.—but also for removing and carrying away the material which, having performed its office, is no longer of use in the system. These two primary operations are carried out in the animal organism by means of the functions called digestion, assimilation, circulation, respiration, excretion, etc. Without attempting to explain any of these vital processes, it will be well to trace the course of the materials consumed in the food to the places they occupy in the various organs and secretions of the system.

The food eaten by an animal, after mastication in the mouth, is received into the stomach, where, by the admixture of several secretions, its nourishing portion is changed, modified, and altered, so as to adapt it for use in the animal system. Amongst these changes the most remarkable is the conversion of the insoluble nourishing principles into forms that are soluble in water, and that will admit of absorption. In the case of ruminating animals—a class to which most of our domestic animals belong—these chemical changes in the food are effected by the secretions of a system of stomachs, or rather divisions of the stomach, which need only be mentioned in this place. The altered food, after the addition of bile, pancreatic juice, etc., next passes into the intestines or bowels, where important chemical changes occur, and the separation of the nutritious from the non-nutritious substances is effected, the former being absorbed and collected by a series of vessels which finally convey the nourishing portion of the food to the blood; the useless matter—the indigestible woody fibre, etc.—of the food passes on and is expelled in the solid excrement. Having reached the blood, the soluble matter is carried by it to every part of the frame, for this fluid penetrates to every organ of the animal system, and is the source from which all new material is derived. Thus the bones, the flesh, the gristle, the milk, etc., are each prepared from the materials of the blood; each organ or tissue draws upon the blood for the constituents it requires for its sustenance or growth. To compensate for this impoverishment, the blood is enriched and its strength sustained by the constant addition of fresh material prepared from the food, as above described. The blood is also the vehicle by which the worn-out matter is carried away, and conveyed to those organs whose special office it is to free and relieve the system of these waste substances; but such is the beautiful economy of Nature, that while, on the one hand, useless materials are removed from a place where their presence is an encumbrance, they are by the same organs converted into compounds altogether as useful and indispensable in some other department of the system. Thus, for instance, the liver is one of the most important organs of the body, inasmuch as, while it relieves the blood of a certain kind of impurity, at the same time it prepares from those impurities the bile, one of the secretions indispensable for the proper digestion of the food. Another example of these organs, appointed for freeing the blood of its impurities and at the same time performing an essential office in the general economy, may be found in the lungs. In these organs the blood gives up the carbonic acid gas resulting from the oxidation of carbon met with in its passage through the body, which, together with water, escapes in the breath. At the same time it absorbs oxygen, which by this means can now be carried to every part of the structure, in order to effect the above changes, and also to produce sufficient heat for maintaining the high temperature necessary to the performance of animal functions. So important is the presence in the system of a due amount of heat or warmth, that a considerable portion of the natural food of animals consists of principles intended, as one of their chief uses, to provide a supply of respirable materials, or, in other words, to furnish fuel for this slow process of combustion. The substances alluded to in the foregoing analyses, under the name of respiratory or heat-giving principles, belong to this class of bodies. An arrangement has been provided by Nature for economizing this respiratory material; whenever more of these compounds are supplied to the blood than can be disposed of by oxidation, the extra quantity is stored up in the shape of fat. Hence these respiratory compounds—as oil, sugar, starch, etc.—are also called fat-producing substances, although it appears that fat is to some extent formed from the albuminoids. From the above brief sketch of the operations involved in the process of animal life we may arrive at the following conclusions :—

1. That as every movement of the animal body is attended by a waste of substance, and as this waste can only be made good from materials supplied in the food, it follows that the greater the amount of exertion an animal undergoes, or the harder it is made to work, the more food it will require, and if this is not supplied, the health of the animal will be impaired.

2. That as the nourishment of an animal depends upon the amount of food digested, and not upon that eaten, it is clear that, however rich in nourishing principles a particular kind of food may be, unless it is also digestible it will be of little service in the animal system. Further, it is known that the digestibility of food varies with different kinds of animals; so that what may be wholesome food for one sort of animal may not be so for another. For this reason the value of feeding-materials cannot always be judged from their composition. But the farmer by knowing the requirements of his animals is able to suitably blend and adapt their food.

3. The food must contain materials capable of building

up and renewing the muscles, bones, and tissues, and every part of the animal body wasted by exertion ; it must also contain materials for sustaining the process of respiration and for producing fat. This latter substance, although invariably present in the animal system, is increased in quantity whenever the amount of respiratory materials supplied exceeds that required for the production of heat through the lungs : thus, the superabundance of respiratory food is stored up and preserved in the shape of fat until required.

In many respects the composition of the bodies of animals resembles that of plants. In each race of beings we find the same ultimate elements, in many cases arranged in the same groups ;—the chief difference consists in the relative proportion of the two principal kinds of compounds so often referred to as nitrogenous and non-nitrogenous principles. In plants, the simpler carbonaceous or non-nitrogenous substances, as starch, woody fibre, etc., form by far the greater portion, and the choicer albuminoids form but a small proportion of their bulk. In animals the case is different : a large proportion of their bulk consists of complex nitrogenous compounds, while the simpler carbonaceous substances are present in smaller quantities. As in the case of plants, the bodies of animals contain a large proportion of water (roughly speaking, about one-half), and the dry substance consists of organic or combustible matter, and inorganic or mineral substances. The organic portion of animal matter is remarkable for the large proportion of nitrogen it contains ; the mineral portion consists of the same materials which compose the ashes of the plants, but differently arranged. It need scarcely be said that the following general remarks apply more particularly to the domestic animals usually reared on the farm.

The organic portion of animals, like that of plants, consists of a number of organized compounds or proximate principles ; these compounds, together with certain of the mineral constituents, make up the various organs of which the animal structure is composed. Many of the proximate principles found in the bodies of animals are identical with those existing in smaller quantities in plants ; indeed, as before hinted, plants prepare these compounds for the use of animals ; for instance, there is a substance obtained from the blood of animals called fibrin, which is closely allied to the gluten of grain. Again, albumen is another constituent of the blood of animals, and is also found in the juices of vegetables ; as in cabbage, etc. Another instance may be mentioned in the case of casein, or the curd of milk. This substance is chemically identified with legumin, the nitrogenous principle of peas, clover, etc. Besides these materials, directly derived from plants, there are found in the bodies of animals certain compounds peculiar to animal life : in most cases these are secondary products, or combinations produced from the partial destruction of the primary or albuminous compounds. Such are the gelatinoids, of which the best known is gelatin, prepared from connective tissue, the organic matter of bones, etc., by boiling with water ; another abundant substance originating from albuminoids is keratin, this being the chemical name for the chief constituent of horns, claws, nails, feathers, hair, and wool : it is noteworthy that this substance contains more sulphur than the albuminoids. Another important constituent of the animal body is fat. This compound is supplied ready-formed in feeding-materials, and is also prepared in the animal organization from starch, sugar, and other respiratory materials of the food ; also to a less extent from albuminoids, as we have already noticed.

The inorganic or mineral portion of animals is remarkable for the large proportion of tricalcic phosphate of lime it contains. This material exists chiefly in the bones, nearly two-thirds of which consist of this substance. The necessity of some earthy material to give strength and rigidity to the bones of the animal frame is obvious ; but why phosphate of lime should have been selected for this purpose we cannot surmise.

In less abundance, mineral substances are present in every part of the animal organism. In blood, flesh, etc., mineral salts exist as essential constituents ; the two just mentioned by name containing considerable amounts of sodium and potassium salts respectively.

As all the above-mentioned constituents of the animal frame, both organic and inorganic, are constantly being worn away and diminished by exertion and labour, and can only be renewed from the food, it is clear that to preserve an animal in a state of health, the diet supplied to it must contain in sufficient quantity all the materials provided by Nature for this purpose. If improper food is given, or, in other words, if any of these several materials are omitted, more or less derangement must ensue. Thus we may conclude that mixtures of substances containing a due proportion of each of the materials required in the animal economy is the only kind of food upon which an animal will thrive or, for any length of time, exist. Of course, the composition of the food supplied to domestic animals may be varied to suit the purpose we wish them to perform. For instance, in the case of fattening cattle, the food supplied should consist largely of fat-producing materials, as the greater part will be disposed of in the development of fat ; the other requirements of the animal being reduced to a minimum when certain precautions as to movements, temperature, etc., are taken. In the case of working horses, much of their food is of course used for the production of energy or work ; and although in this, as in all cases, a proper proportion of albuminoids must be given, an excess is not required under normal circumstances to enable an animal to work satisfactorily ; in other words, carbohydrates, fat, etc., are quite able to serve as fuel for this purpose, a fact already commented upon in an earlier chapter.

Regarding animals merely as sources of beef, mutton, and other kinds of animal diet, they consist, for the most part, of bone, flesh, and fat. The first-named of these materials has already been sufficiently described ; the two latter must now occupy our attention.

When the flesh or lean part of meat is washed in running water for a length of time, everything soluble will be removed, and a white stringy substance left. This substance is called fibrin, because it forms the greater part of the fibres of muscle. The flesh consists of various soluble matters distributed through this fibrous substance, the red colour being due merely to the blood left in the smaller vessels. The soluble components of meat constitute its most valuable portion when consumed as human food. The extracted juice of flesh is found to contain several highly valuable mineral salts, albumen, and small quantities of certain peculiar principles called kreatine, sarcine, and carnine. Its general composition may be stated as follows :—

AVERAGE COMPOSITION OF FLESH.

Water	78.0
Fibrin, vessels, nerves, cells, etc.	17.0
Albumen	2.5
Other constituents	2.5
	100.0

The cooking of meat should be done in a manner that prevents the loss of the highly-nutritious soluble matters. For this reason stewing is the most economical way of cooking meat ; and boiling, for the same reason, the most wasteful. At the same time, by proper management, the loss of these valuable matters from meat by boiling may to a great extent be avoided by recollecting the following facts, which may not be known to everyone :—Amongst the soluble matters found in meat is albumen ; this substance, which at ordinary temperatures is soluble in water, possesses the peculiar property of becoming insoluble, or of coagulating, by heating. We must all have noticed this property of albumen in the white of eggs, which consists almost entirely of this substance, together with water.

If meat is placed in cold water, and the whole gradually raised to the requisite temperature for cooking it, a great loss of nourishing materials is incurred; since the water will have an opportunity of extracting and dissolving a great portion of the soluble and more valuable constituents; but if the meat is placed at once in boiling water, the albumen contained in the outer layer will be coagulated, or become solid, and thus form a shell or case, which prevents the removal of the soluble materials contained in the inner portions of the meat. But, as is well known, this latter plan is incompatible with good cookery; the meat by this treatment is found to become "hard"—a quality, of all others, that should be avoided in articles of animal diet.

The proper way of boiling meat seems to be to make a portion of the water boil in the vessel that is intended to receive it, then to add the joint and boil for a few minutes, now add more cold water, until the temperature of the whole is reduced to that best suited for the purpose: this temperature is about 160° of Fahrenheit's thermometer.

Most animal and vegetable fats are found to consist of three distinct principles, viz., stearin, palmitin, and olein, the prevalence of one or another giving the distinctive characters to different varieties peculiar to particular species of plants and animals, stearin predominating in solid and olein in fluid fats; for instance, mutton suet is chiefly stearin, the hardest of the three principles, with a little palmitin and olein; beef suet contains more palmitin; olein being a fluid, the character of a fat will be greatly influenced by the proportion of this constituent it contains. This substance may be extracted from most natural fats by pressure.

Margarin is the solid fat of butter, and constitutes a great part of the fat of some animals, including man.

Some doubt would appear to prevail as to the separate existence of this substance, there being reason to suppose that it is a mixture of stearin and palmitin.

Having now described the general properties of the flesh of animals as supplied for human food, little remains to be said of the individual character of that of particular species of animals, since these differences depend more upon the mechanical texture of the flesh than upon any difference in composition ; yet, at the same time, the characteristic flavour of the flesh of different domestic animals might, no doubt, be traced to the presence of minute quantities of peculiar organic principles. The flesh of the same kind of animals is also subject to great variation, depending on the age, sex, condition, habits, and breed of the individual, and, to a greater extent, on the kind of food used in feeding. The value of meat as human food is regulated by the amount of nourishing principles it contains, as well as by the degree of facility with which these substances can be digested. The flesh of game generally possesses both these qualities in a high degree ; and as, moreover, it yields, on cooking, a larger quantity of flavouring matter than most other kinds of meat, we are justified in supporting the high character of this description of animal food.

Cakes and other Purchased Foods.

Before proceeding further it becomes desirable to offer some remarks upon the various kinds of purchased feeding-stuffs, those produced upon the farm having already been dealt with. As linseed cake must be considered upon the whole the most serviceable material of the kind, we will notice it first. Much has been said regarding the purity of these cakes, and indeed it is important that the farmer should get what he wants and pays for ; properly screened seed should therefore always be employed, and the necessary precautions taken to prove that neither by accident nor fraud has an inferior cake been supplied when a pure one has been ordered.

The term "pure" can only have a relative meaning in practice; we should, therefore, on this account, prefer to consider a cake so defined as one that has evidently been carefully prepared from thoroughly screened seed.

Mixed cakes are preferred by some buyers, as they are cheaper, and under some modes of feeding are said to do as well as any, though this may be doubted. If mixed cakes must, however, be dealt in, it is better to use nothing but bran and pollards, or similar farinaceous material which is known to be good food and goes well with linseed as a feeding-mixture, whether in cake or otherwise, the only question being one of price.

We should advise none but pure cakes to be used, because we believe they are cheapest in the end; and provided they meet requirements in the way of oil and general composition, and are in a fresh and sweet condition, it matters little, we consider, whence they are derived or what kind of linseed they are made from, or what brands they bear. Buyers must of course expect to pay a fair price for such cakes, and unduly cheap ones, alleged to be as good, should be regarded with suspicion.

The standard of 95 and 96 per cent. has now come into general use, but has not, we think, yielded altogether satisfactory results; the fact that this gives no guarantee of the amount of oil present, which is certainly one of the most important items, if not the most important, in its composition, is yet one on which both buyers and sellers are often quite in the dark. A linseed cake we lately analysed contained as much as 16½ per cent. of oil, which is rare in an English cake, and would probably arise from some inadvertence on the part of the crusher, yet for agricultural purposes it would possess a marked superiority. It is very noteworthy that quite lately the variations in the proportion of oil have been remarkably wide.

A drawback to the use of inferior cakes, apart from their lower and uncertain value as food, is the fact of their containing a much larger proportion of foreign seeds and rubbish, some of which may at times exercise an injurious effect on the animals fed.

How far we should act wisely in selling grain and buying cake or other foods, will always be a matter open to discussion, and depends, of course, mainly on the state of the markets; but, apart from this, there will always be a certain proportion of inferior grain which can obviously be used to best advantage in home-feeding.

For almost all purposes linseed cake is too concentrated a food, and both economy and effectiveness may be secured by diluting it, so to speak, with some farinaceous or less nitrogenised material. We thus obtain a mixture which resembles some of the lower-priced cakes sold and used as linseed cake, but with the advantage that we know the precise nature of the diluent, which is not always the case with mixed cakes; and the preference given by some buyers to the latter shows that such mixtures have many practical merits to recommend them.

For most purposes we may thus dilute pure linseed cake with one-third to one-half barley meal or wheat meal, or, if greater economy is desired, say equal parts of the meal and dried grains as a diluent. A small proportion of ground carob beans and a sprinkling of common salt add much to the efficiency of such mixtures.

ANALYSES OF LINSEED CAKES.

	1.	2.	3.
Moisture	9.60	12.10	11.34
Oil	13.10	8.02	9.23
*Albuminous compounds	29.87	29.37	27.50
Mucilage and other carbonaceous principles ...	33.96	36.83	34.30
Phosphates, etc.	5.04	4.80	4.73
Fibre	7.63	8.12	8.66
Insoluble matters	.80	.76	4.24
	100.00	100.00	100.00
*Containing nitrogen	4.78	4.70	4.40

No. 1 is a pure cake of excellent quality.
No. 2 a pure cake, but low in oil.
No. 3 an inferior cake with much dirt.

Decorticated Cotton Cake.

This material next claims our attention, for it appears to be greatly liked in practice ; the high percentage of nitrogen gives it a special value for manurial purposes, this often forming a consideration of much importance in selecting a diet for our stock, and the relative usefulness of various foods in this respect will often determine our choice. We must here say a word as to the care required in dealing with these cakes ; first we must refer to the extreme hardness of the greater number. To prevent this is difficult, as, of course, the object of the manufacturer is to extract as much oil as possible, and modern machinery enables him to accomplish this with great completeness: a result which, however satisfactory from his point of view, is an unfortunate one for the farmer, for cake of this description must be considered of decidedly lower relative value than one of a softer nature. Care must also be taken to avoid an excess of cotton fibre in both varieties of this cake, as it is apt to form lumps within the animal's stomach, which may give rise to considerable trouble.

The amount of moisture is also important in cakes of every kind which have to be kept some time, as their tendency to mould is much influenced by this item. This applies especially to cotton-cakes, any suspicion of mould in which should be a just cause for rejection, as it sometimes leads to loss when supplied to animals, from causes not clearly understood. We should, therefore, prefer a cake of lower quality in good condition to one of higher quality with any doubt as to mould, freshness being in these cakes a consideration of special moment.

We must regard this subject as a matter of the highest importance, for instances are by no means rare of mischief happening to stock fed upon such cakes and meal made from them, the effects produced leading the purchaser to believe that some added irritant poison is present, although careful research has quite failed to support his view. Especial caution is necessary when buying cotton-cake meal, for in this the tendency to mould seems greater.

We have only mentioned these points, however, for the purpose of putting our readers on their guard, and believe that if used in a fresh and wholesome condition this feeding-material is of great value, an opinion which is well supported by practical men, for it has been said to be unrivalled as a milk, butter, and flesh producer. Both theory and practice concur, however, in the belief that cotton-cake should always be used in combination with some farinaceous matter ; so concentrated a nitrogenous food must be supplied to stock under one year old only with the very greatest care, and it is said that on no account must we use it for cows on the point of calving, nor for a month after.

While speaking of calves we may perhaps say that in feeding them all irregularity is to be avoided, and when supplying them with milk-substitutes it is, of course, necessary to do so in the form of gruel.

Taking all the circumstances into account, we are compelled to believe that, generally speaking, a good pure linseed cake is to be preferred to any kind of cotton-cake.

Undecorticated Cotton Cake.

In these we have, of course, a large proportion of fibre, but, when carefully used, more satisfactory results are obtained than might at first sight be thought probable; the same precautionary measures should, however, be taken as with the last-mentioned material against mould, etc. When buying cotton-cakes and meal, it would seem the farmer's wisest policy to do so in comparatively small quantities at a time, as he then runs less risk ; manufacturers will also find it to their advantage if they encourage such a practice, for in the event of anything going wrong the blame will certainly fall upon them. The undecorticated cake is said to be useful in preventing scour.

ANALYSES OF COTTON CAKE.

	1.	2.	3.
Moisture	8.50	7 24	6.54
Oil	13.76	17.65	5.76
*Albuminous Compounds	44.50	37.00	21.25
Carbonaceous Principles	20.32	27.76	43.07
Phosphates, etc.	6.72	5 13	4.30
Fibre	6.20	5.22	18.76
Insoluble matters	traces	traces	.32
	100.00	100.00	100.00
*Containing nitrogen	7.12	5 90	3.40

No. 1 is a decorticated cotton-cake of good quality.

No. 2 is an example of a fair sample of the same containing an exceptionally high percentage of oil.

No. 3 supplies an instance of undecorticated cotton-cake.

Rape Cake.

We must advise very great caution in using this as a food, on account of the unfortunate results likely to follow if a sample containing much mustard is supplied to stock, this being an impurity often present. For some purposes we may apparently employ it with a certain amount of advantage, but, considering that other much superior cakes may now be obtained at reasonable prices with infinitely less risk, we cannot recommend farmers to use this largely Rape-cake is now generally used as meal for manurial purposes, and is referred to in the next chapter.

Malt Cake, Cocoa-nut Cake, Palm-nut Cake, Etc.

The first is a material that has now been introduced for some years ; it is of good feeding value, very regular in composition and possesses an exceedingly attractive smell and flavour, indeed, we believe that a very much larger quantity than is at present placed on the market would readily find purchasers.

Cocoa-nut meal and cake are useful when obtainable in sufficient quantity and under satisfactory conditions as to price, etc. Palm-nut cake and meal also meet with the approval of many who have used them, although their physical qualities are not very prepossessing at first sight.

Other articles used for feeding-purposes we may mention are brewer's grains in a moist and dried state; these are very serviceable, and may be well recommended. When obtained dry we, of course, gain the advantage of having so much less useless water to deal with—a matter of great importance when carriage has to be considered; they serve admirably as a means of diluting richer food, and, indeed, possess in themselves a higher feeding value than we might suppose.

A sample of these grains may also be examined for foreign bodies, just as we do corn, a point which gives them in this respect a superior position to all kinds of meal, wherein almost anything may evidently be concealed.

Rice Meal

serves as an illustration of a material which often suffers in the way we have just referred to, much dirt frequently being present derived from the sweepings of warehouses, etc., which may, of course, contain all manner of injurious matters; in fact, a sample has quite lately come under our notice which we should consider far too dirty for feeding-purposes, hence it is evident that much care is necessary in selecting foods of this description.

Bran.

This is an excellent material if properly used; like brewer's grains it forms a useful producer of milk. The peculiar physical character of this food appears to give it somewhat laxative properties, for which reason some care is requisite in supplying it to our stock; mashing and mixing with peas, beans, or oats seem the most suitable methods of preparation; if mixed with linseed it may also be used with great advantage.

Indian Corn or Maize

may be mentioned as a feeding-material worthy of far more attention than it receives even now, because for maintenance purposes it appears to form an admirable food, a view which the increased consumption of late gives us reason to suppose is becoming more generally adopted.

ANALYSES OF

	Brewer's Grains.	Vinegar Grains.	Dried Grains.	Rice Meal.
Moisture	75.42	88.30	8.60	9.60
Oil	traces	traces	5.63	2.96
*Albuminous Compounds ...	4.38	1.67	18.46	12.25
Carbonaceous Principles ...	14.41	7.48	49.02	54.86
Phosphates, etc.	1.16	.25	4.07	4.63
Fibre	4.63	2.30	14.22	13.20
Insoluble matters	traces	traces	traces	2.50
	100.00	100.00	100.00	100.00
*Containing nitrogen ...	.70	.30	2.95	1.96

Mixed Foods.

The number of these, both as cakes and meals, is now very great, and while some are well worth the price charged, others are almost useless; it is, however, impossible to ascertain their value except by means of a chemical analysis, for, as we have already hinted, almost anything may be introduced by fraudulently-disposed persons, and easily escape detection when ground up with other constituents. We, however, feel fully justified in saying that, providing reasonable precautions are taken, the farmer may use with advantage the better classes of calf meals, milk substitutes, etc. In discussing these we must once more refer to linseed cake, which is of much value as a component of mixed feeding-meals, calf-foods, etc. Its mucilaginous character is especially useful in imparting "body" to the "gruel" made from the latter preparations, which now supply a valuable aid in calf-rearing; and while itself one of the most suitable materials for the purpose, keeps in suspension the other ingredients of which the mixture may be compounded.

In mixed feeding-meals for general purposes it is a valuable component, and well worth its somewhat high price, as, apart from its merits already noticed, it is one of the few substances sufficiently rich in nitrogen to raise the average of this element when articles poor in it are used. Pea, bean, and lentil meal are also suitable for supplying nitrogenous compounds, while maize, barley, and wheat-meal afford a good farinaceous basis to be supplemented by bran, palm-nut meal (to supply oil), carob beans, etc., according to price. Small quantities of spice and flavouring substances are also sometimes added, and an attractive flavour undoubtedly adds to the practical effect of mixtures of the kind; for although this fact has been ignored and even ridiculed in some quarters, it is only reasonable that a tasty and appetising flavour should possess attractions to the animal as well as to the human palate.

We have always held that a better effect is obtained from such mixtures when skilfully blended than from the same materials separately used or in the ordinary way. There is no possible reason why the farmer should not himself prepare such mixtures, if he possesses suitable means and is so disposed; but it will be found that even so simple an operation as mixing dry meals properly (apart from the grinding) requires some special arrangements and experience. If the materials admit of being ground together, so much the better, as it will render the mixture more intimate; but the most important point is to have it uniform throughout the whole—that is, every part to contain the same proportions, and this is not so easy as sometimes supposed. Hence it may suit the farmer's purpose better to buy such mixed foods when compounded on sound principles and at a fair price. Mixtures of the kind are often pressed into cakes which have certain advantages, such as preventing waste, better intermixture of components, etc. Some mixtures have already been given under linseed cake.

The "albuminoid ratio", in connection with the mixture of foods, is a matter of some importance, and is a term now becoming better understood. Some confusion appears to have arisen concerning it, but in reality there is little difficulty involved. To avoid any misunderstanding, however, the wisest course will be to quote the definition given by its originator, Mr. Warington, who states this expression to mean "the ratio or proportion of the albuminoid to the non-albuminoid digestible constituents of food". By means of an acquaintance with this ratio of foods we are able to compare them closely, and blend accordingly for various feeding-purposes.

It is important to understand clearly that we are here dealing with *digestible* constituents, hence the proportion must vary more or less with the kind and breed of animal. When a true albuminoid ratio is required, the calculation must be made on the basis of actual albuminoids present, and not only upon the nitrogenous substances. For reasons previously given this distinction is not of such importance in the case of cakes and foods of a similar nature as for roots, etc. Should further information on this subject be required, we recommend our readers to an article of Mr. Warington's published in the *Live Stock Journal Almanack* for 1891.

Dairy Produce.

The gradual extension of dairying appears to offer a resource to depressed agriculture in many places. It is true the price obtained for milk by the farmer is so low as to be scarcely remunerative, and to offer little temptation to new-comers; but this should only induce him to try to convert his supply into a more profitable form—say, fresh butter, for the highest class of which there appears to be a good demand. The production of butter is not a difficult process, depending mainly on attention to temperature and close observance of details, such as almost any sensible person should readily acquire ; while the cream-separating machine is a real boon in connection with this work which farmers are only beginning to avail themselves of. The "separated milk" is a more saleable article than skim-milk, and the market for it is extending : it is also more adapted for a general beverage than new milk, which is simply a rich liquid food. Choice English butter is preferred by many to the mixed foreign article which at present is said to monopolise three-fourths of the London trade, chiefly through possessing the enormous advantage of reliable uniformity; the absence of this property appears to be the weak point in the home supply, which must be overcome if any larger share of the trade is to be regained.

The operations of the dairy may be aptly described as chemical processes on a large scale, for which reason many precautions similar to those observed by the chemist in his laboratory are necessary, such as considerable exactitude and careful attention to so-called minor details. A lack of these will possibly involve the loss of much valuable material, and certainly greatly reduce any profit arising from the sale of the products; as we cannot always expect to find these qualifications in servants, the well-known scarcity of good dairymaids is explained. This reproach is one, however, which should speedily be removed, for excellent instruction is now far more readily obtained than formerly. The most important raw material—if we may use the expression—of the dairy is of course milk. We shall therefore devote our attention to it first.

MILK.

As one would readily imagine, the secretion provided by Nature and supplied by the mother to her offspring corresponds in its composition to that of the young animal it is intended to nourish. Milk is particularly rich in every kind of material required for the development of the animal frame; it contains nitrogenous or flesh-forming substances, respiratory compounds, and the valuable mineral salts needed for the formation of bone and other parts of the system. Moreover, all the substances are of the best description, that is to say, are of a kind that can readily be assimilated by the yet feeble organs of the young animal; and further, the proportions of these constituents are adjusted to the wants and capabilities of the animal at this early stage of its existence.

COMPOSITION OF MILK.

	Cow.	Ass.	Goat.
Water	87.20	90.05	85.54
Fat (butter)	3.35	1.47	4.08
*Casein, albumen, etc. ...	3.15	1.82	3.65
Milk-sugar, etc.	5.56	6.23	5.95
Mineral matters	.74	.43	.78
	100.00	100.00	100.00
*Containing nitrogen	.50	.29	.58

The milk of different animals varies as much in its external properties—its opacity, taste, density, etc.—as in its composition. As the milk employed in the production of butter, cheese, and all other dairy produce is exclusively that of the cow, the following remarks apply more particularly to that description; even this also varies greatly in composition, etc. Hence an analyst should exercise great carefulness in condemning a sample of milk. The limits of composition below which an ordinary specimen obtained from several cows under normal conditions is supposed not to fall, and still be considered genuine, are as follows:—

Total solids	11.5	per cent.
Solids not fat	8.5	,,
Fat	3.0	,,

Slight variations from this standard should not, however, be too severely dealt with, but judgment gained by experience must be brought to bear upon individual cases. The specific gravity of milk ranges between 1.029 and 1.035, but, when deciding upon the purity of a sample, its determination is not of great value.

Milk is said to be a natural emulsion, or a fluid containing a number of fat globules diffused throughout its substance, stated to vary in size from $\frac{1}{2000}$ to $\frac{1}{20000}$ of an inch in diameter. The larger globules are of greatest value when cream is desired, as they rise sooner, a more complete separation also being effected ; but for the production of cheese, milk containing those of smaller size is perhaps most suitable. As these particles of fat are insoluble in water, they give rise to the opaque white appearance common to all descriptions of milk. On standing, the greater portion of the fat rises to the surface and forms the cream. The globules of fatty matter are inclosed in little skins or shells ; some uncertainty appears to exist as to the exact nature of these coatings. The opinion of some authorities would seem to be that a true membrane encloses the fat, while others think the isolation of globules is attained by some less definite means ; however this may be, by violent agitation they are broken, and the fatty matter collects together in the form of butter. The composition of milk of course varies to as great an extent as any other kind of agricultural produce, being affected by the food supplied to the cow, the breed of animal, its state of health, the treatment it receives, the time that has elapsed since calving, also the time of milking, and a variety of other circumstances which need not even be mentioned here. The proportion of fat in milk is apparently most under the farmer's control, other constituents being less easily influenced, hence the desirability of applying skill and care when arranging diets for milch-cows, especially if butter is our chief requirement; although such animals must always receive liberal feeding, which must at the same time be of a nitrogenous character. Should this important matter of feeding be neglected, satisfactory results cannot be obtained, for milk production is an exhausting process, and to expect a larger output of a manufactured article without a corresponding increase in the supply of raw material, or the formation of a first-class product from indifferent constituents, is of course unreasonable. It is undoubtedly a good plan to watch carefully the milking record of each cow, varying the character and quantity of its food accordingly.

By referring to the foregoing table, we notice that the bulk of milk consists of water, the solid constituents it contains being either held in suspension, as in the case of the fatty matter, or dissolved in it, as the casein, sugar, and saline or mineral portion. We have already noticed the form in which the fatty matter or butter occurs in this secretion. The casein of milk is a substance belonging to the natural group of albuminous or nitrogenous compounds so often referred to as flesh-forming materials. Casein resembles very closely the allied compounds already described, as gluten of wheat, albumen, legumin, etc. This substance is insoluble in pure water, but dissolves in that containing alkalies, as potash and soda; hence the casein of milk is kept in solution by a small quantity of these compounds also present. If by any means we remove or overcome this alkaline substance, the casein is separated in an insoluble form. This operation takes place when milk is curdled. Thus we perceive that one of the purposes fulfilled by the mineral or saline constituents is to keep the casein in solution. The separation may be accomplished either by means of rennet whose action is that of a ferment, or the addition of an acid, thus differing from the albumen present, which becomes insoluble when milk is boiled, forming a constituent of the well-known skin or scum produced under the circumstances. The primary office of the mineral substances is, however, to supply bone-material to the young animal which the milk is intended by Nature to nourish. Hence, amongst other valuable mineral constituents, it contains a large proportion of phosphoric acid, the material, it will be remembered, so essential in the formation of bone.

The sugar of milk imparts to it the well-known sweet taste; but the sugar found in milk is somewhat different from that prepared from the sugar-cane, or from that belonging to fruits: its chemical name is lactose. Milk-sugar, when separated from the other components by suitable means, is a hard white substance, much less crystalline and sweet than ordinary sugar. Milk is an exceedingly unstable mixture. As it is intended by Nature to be at once transferred from the receptacle of the mother to the body of the young animal, no provision is made for its preservation when removed from the living structure. Hence, by exposure, milk quickly undergoes change through the agency of minute living organisms; and, if left for any considerable time, these changes are so extreme as to render it unfit for an article of diet; if measures to exclude these organisms are taken, milk may be preserved without appreciable alteration. The first of these changes is the turning sour or becoming acid, and a consequent curdling or separation of the casein. This change is due to the formation of a peculiar acid called the acid of milk, or lactic acid, from the materials of the sugar present. This transformation in the sugar of milk is effected by the means referred to above; just as in the fermentation of beer or bread, the well-known yeast, also a small organism, first sets up the tendency to change. This same acid is one of frequent occurrence in other mixtures than milk: the sour taste of brewer's grains or of raw malt, and the mash on which pigs and other cattle are fed, is due to the presence of this lactic acid, which is always found when vegetable substances of this description ferment. The simultaneous curdling of the milk with the formation of this acid is explained by the fact already pointed out in connection with the properties of casein. As casein is only soluble in the milk so long as an alkali is present in a form capable of dissolving it, we see that as the first effect of an acid produced in the mixture will be to neutralise this alkali, the curd or casein, being now left without a supporter, must separate. The same effect can be produced artificially by the addition of any other acid; as vinegar (acetic acid), muriatic (hydrochloric) acid, etc. The separation of the curd is, however, most advantageously effected by the addition of some substance which rapidly brings about the wished-for result, without exciting any other less desirable change: such a substance is rennet, the prepared membrane of the stomach of a calf.

Several methods of preserving milk have been suggested, one being to add some substance, as salicylic acid, boracic acid, etc., with the object of retarding decomposition. Different opinions are held as to the effects likely to follow the use of these materials in our food; those in their favour contend that the small quantities employed are quite harmless. Whether this is so or not, we should consider it far more satisfactory to avoid them; the application of some equally effective and workable method, if such can be found, is much to be desired.

As the changes occurring in milk are so largely due to living organisms, we naturally suppose that by striking a blow at them we can do something towards retaining its sweet condition for a longer period; the following remarks will therefore render clear to us the reasons why certain processes are carried on in the dairy—for instance, the action of these organisms is impeded by cooling the milk to between 50° and 55° Fahrenheit; again, exposure to a temperature of 170° Fahrenheit is found to kill most of them. In hot weather a good plan is first to heat the milk and afterwards rapidly cool it, alternate heating and cooling being the most potent means of destroying life of this description, which is sometimes retained with astonishing tenacity under what we might at first almost consider impossible conditions.

The sterilization of milk has been suggested as a means of making it possible to import supplies from abroad; manifestly, however, the carriage of a bulk of liquid renders the question of freight one of far greater difficulty than is the case with condensed milk of various kinds.

Skim milk, or the more recent separated milk, is, we believe, deserving of far greater attention and appreciation than it at present receives, although considerable satisfaction may be derived from the fact that its sale appears to be increasing. For ordinary drinking purposes we should consider it decidedly better fitted than whole milk, whose fat cannot be essential for such uses; and even in many cases where fat is desirable there seems no good reason why it should not be supplied in another form, for the valuable albuminoids and mineral constituents remain; hence, although doubtless a very good food for calves, pigs, etc., we cannot well regard this as the most satisfactory method of dealing with it, especially as there is good cause to believe that when once its virtues become known to town residents an active demand will speedily arise which farmers would be most happy to meet if they saw how. This inability of producers and consumers of food to meet one another's wants is most unfortunate; indeed, we cannot but feel it grievous to hear of farmers almost wasting this valuable article of diet, and fishermen throwing away their fish for want of a reasonable price, while at the same time we know that to obtain the bare necessities of life is one prolonged struggle with only too many of our fellow-men.

A matter of great importance is to see that our cows are treated with kindness, especially during the operation of milking, not upon humane grounds alone, but also because the richest milk is yielded last, hence anything that would tend to cause the animal to withhold this should be most carefully avoided. Whether the recently introduced milking-machines will prove successful in ordinary practice is, we think, a point which only time can decide; should they do so, a great benefit will doubtless be conferred upon many.

Much has been said concerning the communication of disease through the agency of milk, and there can be no doubt that epidemics have often arisen by such means; for this fluid seems especially adapted to serve as a nutrient medium of organisms, thus promoting their multiplication. Many diseases, as we now well know, originate from these low forms of life; but what, if any, are directly derived from the cow is a contested point. There can, however, be no question that infected water from wells, etc., employed in washing cans and other vessels, has frequently been the first cause of outbreaks, the milk forming an efficient means of distribution: clearly, therefore, sellers of this product should be most careful to assure themselves of the purity of their water.

Having now stated the general properties of milk and its components, let us glance at the almost indispensable commodities prepared from it, viz., butter and cheese.

Butter

consists for the greater part of the fatty matter of milk, but it also contains variable quantities of all the other substances found in that fluid. This is because the separation of the butter from the milk is always more or less imperfect. Hence we find in butter small quantities of water, sugar, casein, etc., accidentally present. The fat of butter, like that of the bodies of animals, consists of a solid and fluid portion: the former consists of the fatty substance called margarine, the material before alluded to as forming a portion of the fat of certain animals (page 183); the fluid portion consists of a variety of olein. Besides these more abundant constituents, there are present smaller quantities of other fatty compounds, to which the pleasant taste and smell of fresh butter are due: it is to the formation of similar compounds, also, that the disagreeable qualities of rancid butter must be ascribed. The alteration and deterioration of fresh butter by keeping is hastened by these impurities, especially the casein, it contains. Hence the necessity of freeing the butter as completely as possible from these substances by washing, kneading, etc. To prevent or arrest these changes, it is common to impregnate the butter with various saline substances, amongst which common salt is most frequently employed. This substance produces an action similar to that induced when it is applied for the same object in the salting of meat, viz., by hardening and contracting the albuminous matter, and preventing its putrefaction.

Churning milk does not appear upon the whole a very advisable practice, hence we shall not consider it more fully.

The old and still most usual plan of obtaining cream by setting the milk in shallow pans has now many rivals, a number of most ingenious devices having been introduced whereby the effects of temperature and specific gravity are utilised to facilitate its separation. One of the most remarkable is, without doubt, the centrifugal machine, in whose construction considerable improvements have been made; by its aid we are enabled to obtain almost the entire quantity of butter-fat present in very excellent condition: this should tend to greatly develop the sale of cream, for which there is always a considerable demand, as in so fresh a state we must of course find it much easier to deal with. When raising cream in shallow pans, care must be exercised to maintain a steady temperature of about 58° to 60° Fahrenheit; evidently, obtained in this way, the product cannot be of equal sweetness to that procured by more recent methods, for the exposure of so large a surface to the air must highly favour the collection of all kinds of foreign matter, with a consequent considerable amount of change in the milk; on the other hand, it is contended that sweet cream requires ripening before churning. We recommend, however, that this should not be carried too far. We shall not find much difficulty in understanding that cream ripens most readily in summer, also, that to produce good results the ripening must be uniform; on this account it becomes important to stir the contents of the vessel from time to time.

The plan of adding to sweet cream a little butter-milk, and warming for the purpose of ripening it before churning, appears to have some advantages.

Temperature is another highly important matter in butter-making. Although no hard-and-fast rule can be laid down, the following may, however, be taken as ordinary limits: in summer from 55° to 58° Fahrenheit, and in winter from 58° to 63° Fahrenheit. About the same variations must be allowed in the employment of sweet and sour cream respectively; in the former case, rather lower temperatures are perhaps desirable. We are now able to see how important an instrument in the dairy the thermometer is: indeed, using it or not makes just the difference between scientific method and the rule-of-thumb; we may also learn one of those lessons which practical chemistry is constantly teaching us, viz., how easily we may make a mistake or be deceived by appearances, at the same time pointing out how we can make sure of each step we take.

It would seem desirable to have the temperature of our churn about the same as that of the cream we place within it. The process of churning is one requiring great watchfulness to avoid carrying it too far, or in any way interfering with the quality of the butter, a result which happens very readily. It remains to be seen how far the appliances introduced to supersede the churn will prove successful. We may accept the following statement as a rule, that the more granular butter is the better; any injury to texture or sign of greasiness must therefore be most carefully avoided, this forming one objection to overchurning, also to overworking; another being the difficulty experienced in washing properly if the lumps are too large. It has been said by an excellent authority that churning should not occupy less than twenty nor more than forty minutes. Very great attention is necessary to make sure the washing is thorough, this being best done in the churn, as the keeping properties of butter depend very largely upon the extent to which the removal of casein, etc., is carried. Working to expel water, etc., must be carefully conducted, while neither in washing nor consolidating should the hands on any account be used. From the foregoing remarks it is evident that we must treat this product with care and gentleness in every stage of its preparation.

There can be no question that we do not produce anything like the proportion we should of our butter-supply, a fact to be deeply regretted, for no satisfactory reason exists to account for this state of things; the only difficulty is the varying nature of that made in this country. We think, therefore, the establishment of butter factories in suitable districts a desirable step, as by this means one method of procedure could be adopted, and uniformity obtained. In making such an arrangement minor difficulties will, of course, have to be overcome, the chief of which is perhaps a satisfactory disposal of separated milk.

The system of mixing and grading butters is open to this objection, that their texture must be seriously interfered with.

The flavour of butter greatly depends upon the food taken by the animal, for which reason some kinds, such as turnips, are not desirable. For the same reason butter obtained from the milk of cows fed upon grass has the finest character in this respect.

Cheese

is essentially the casein of milk, mixed with variable quantities of fatty matter and its other constituents, more or less changed by incipient putrefaction. The richness of cheese, apart from the natural qualities possessed by the milk from which it is made, depends, in a great measure, on the amount of fatty matter or cream present with the milk before curdling. If cream predominates, the luscious but unstable cream-cheese is formed; if an additional quantity of cream is added to the natural milk, the more permanent and much-esteemed Stilton is obtained. When the entire milk is used, such cheese as Cheddar, double Gloucester, etc., results. If a portion or all of the cream is removed from the milk before being curdled, cheese of a corresponding quality is obtained.

For separating this product, the united action of natural acidity and rennet is perhaps most satisfactory, although much difference of opinion appears to exist concerning the proportion of acid desirable, which is said to influence the ripening and keeping properties of cheese; probably the amount required varies with the different descriptions. There can be little doubt that the best form in which to use rennet is as one of the prepared extracts now sold, for a better idea of its strength and uniformity may thus be obtained—both important matters in the manufacture of good cheese. Temperature is here again of great moment, for unsatisfactory results will follow should the milk at the time of curdling be either too hot or too cold. A useful general range is between 80° and 88° Fahrenheit, the point varying with the season of the year. We can find no good reason why English farmers should not produce fancy cheeses of similar character to those imported from abroad, which are in considerable request. The high price of cream-cheese is apparently an objection to its general use, although its production does not require so much skill as other varieties.

An attempt was at one time made to raise the character of skim-milk cheese by adding some kind of fat; the results, however, were by no means satisfactory.

After removing the pressure necessary for the formation of cheese, the process of ripening has to be undergone. This seems to be carried on best in a curing-room, having a temperature of about 65° Fahrenheit, daily turning being also important.

The quality and richness of cheese are influenced by a host of circumstances; amongst which the character of the soil, the method of preparing, and the subsequent treatment are prominent. The ripening and characteristic flavour of particular kinds of cheese appear to depend chiefly upon the action of organisms, and some attempts to develop desired flavours and growths, by introducing the requisite species, are said to have been successful. The ripening of cream appears to rise from a like cause; also, to some extent, the flavour of butter. Much of all this is, however, at present comparatively untrodden ground, and any statements must be made with considerable reserve. Careful research in such a field is, beyond doubt, much to be desired, although knowledge acquired through practical experience enables us even now to control very largely the development of flavour, etc.

A few words may now be added with respect to the dairy itself, for manifestly this must exert great influence upon the articles prepared therein. With regard to construction, a site giving the least variation in temperature is desirable; dryness and good ventilation must also be secured. In the milk-room a temperature lower than the milk should be assured, as any chance odours are then less readily absorbed. As a rule, however, these must not be permitted, for the flavours of dairy produce are so exceedingly delicate that very little will interfere with them; hence all stables, etc., etc., must be as far removed as possible, and even the household food is better placed elsewhere.

Again, cleanliness in all points is of the very highest importance; merely cleaning in a showy way is not, however, sufficient, for much disturbance may be created and labour expended upon scrubbing, etc.—important matters enough, doubtless, while, at the same time, points even more essential may be easily overlooked. All utensils must also, of course, be most carefully attended to; and it would seem a good plan to rinse those used for milk, especially any constructed of wood, with cold water first, afterwards thoroughly cleansing with hot; by this practice we avoid any risk of fixing albumen within their interstices, which would decompose and probably give some trouble.

CHAPTER VIII.

OPERATIONS FOR RESTORING AND IMPROVING LAND.

Exhaustion of the Soil by Cultivation.

We now propose to inquire into the changes the soil undergoes in ministering to the growth of plants, and from the foregoing chapters we shall be able to understand the causes of its exhaustion. Plants, as we have seen, derive from the atmosphere and from water but a small number of the materials required for their growth ; or, to be more precise, they only obtain from these sources carbon, hydrogen, oxygen, and a little nitrogen. All the mineral substances, and the greater part of the nitrogen they require in the production of the several organic compounds described in the former chapters, must be supplied by the soil; for even the value of free nitrogen to leguminous plants depends upon the existence of certain favourable conditions in the soil. Since every plant thus contains a certain amount of material derived from the soil in which it has grown, it follows that this soil must in all cases sustain a corresponding loss by its production. Hence, through every cultivated crop the soil sustains a loss proportionate to the abundance and richness of the produce ; however fertile or prolific of these materials a soil may be, it must sooner or later show symptoms of exhaustion, or inability to supply a due amount of material for the healthy growth of plants, if a succession of crops is raised upon it, and no equivalent returned in the shape of manure.

These observations apply only to those crops, or parts of crops, that are carried off the land either directly, in the shape of vegetable produce, or in the form of live stock.

When the whole of a plant is returned to the soil where it has grown, an addition, rather than a loss, of constituents is the result, because the soil is enriched by the materials the plant has appropriated from the atmosphere and from water. The extent to which the soil suffers by the various crops raised upon it will thus be chiefly regulated by the manner in which they are disposed of. For instance, a crop of wheat removes from the soil during its growth a large quantity of nitrogen, phosphoric acid, and several other valuable mineral constituents ; and although the greater part of this crop—viz., the straw—is returned to the land in the shape of farm-yard manure, yet, as the chief part of the more important materials is situated in the grain, which in most cases is sold off the farm, the exhaustive effect of a heavy crop of this cereal is accounted for. Again, a crop of roots—as swedes, for instance—requires as much, or more, material from the soil for its development as the wheat-crop ; but as this kind of produce is generally consumed on the farm, often on the ground where it has grown, a less amount of plant-food is lost to the soil, because in either case the greater part of the nitrogen and mineral constituents is returned to the soil in the shape of manure.

This loss of material, incurred by the land in the growth of the crops raised upon it, is felt chiefly in inorganic substances, or the mineral food of plants, which constitutes the ash left on burning. The atmospheric food of plants, with the exception of combined nitrogen, exerts no influence upon the exhaustion of the soil, since the amount of carbon dioxide, etc., in the atmosphere, practically speaking, is inexhaustible ; but as the mineral constituents of crops, such as phosphoric acid, sulphuric acid—a small portion of the sulphur present in plants is so combined as to be removed with other organic constituents upon the application of heat, potash, etc.—are supplied solely by the soil, and the quantities of these materials in a serviceable condition are limited even in the best descriptions, it is chiefly by their loss that the fertility of our land is impaired by cultivation. The amount of nitrogen present in a crop must also be taken into account in considering the extent to which the soil has been weakened. At one time some persons imagined that this element, like carbonic acid, is supplied *ad libitum* to all plants; that the minute quantity of ammonia and other combinations in the air is sufficient to supply all the nitrogen they require; and also that their ability to absorb this ammonia, etc., and, consequently, the amount of nitrogen they receive, is dependent on the quantity of mineral substances at the plants' disposal. In other words, they supposed that the mineral constituents were the only materials required to be supplied to the plants, and that, if these materials were provided in proper quantity, the plants would obtain for themselves from the atmosphere sufficient nitrogen to satisfy their needs in the development of flesh-forming principles. On a former page we have explained how the demands of wild or natural vegetation are met, but concerning cultivated crops it seems tolerably certain that their chief source of nitrogen is that previously added to the soil as manure. Of course, our readers will remember that an exception to these remarks may be made in the case of leguminous plants, although we must clearly understand that in addition to their special source they also use the ordinary means of acquiring this element; and to what extent the one or other method will predominate under varying circumstances is a point about which we appear still to require considerably more information. Thus we may conclude that the nitrogen of most crops, as well as the mineral or inorganic substances, have been supplied at the expense of the soil.

Notwithstanding the considerable amount of plant-food removed, Sir J. B. Lawes has found, by a series of experiments extending over a period of fifty years, that at Rothamsted a succession of grain-crops may be grown upon the same unmanured plots with a better result than we might expect, although the yield per acre is of course small when compared with the English average.

In order that we may form an idea of the extent of the exhaustion, and the quantities of the more valuable materials removed from the land by culture, we annex the following table:—

QUANTITIES OF THE MORE ESSENTIAL CONSTITUENTS OF THE SOIL REMOVED FROM IT PER ACRE BY A CROP OF WHEAT.

	Wheat (grain) of 25 bushels.
Nitrogen	27.90 lbs.
Mineral substance, 26.25 lbs., containing—	
Phosphoric acid	12.07 ,,
Potash	7.86 ,,
Magnesia	3.22 ,,
Lime	.89 ,,
Other less important mineral substances	1.39 ,,

Rotation of Crops.

Another matter connected with the exhaustion of the soil by culture must now be noticed. It is well known that a soil may be exhausted in reference to one crop, and yet be fertile to one of another sort; while it may be incapable of bearing an additional profitable crop of the same kind as that last produced, one of another kind may flourish and come to perfection. This was formerly explained by believing that plants during their growth excreted certain compounds, and that each tribe produced a different kind of excrement, which, although injurious to the plant that produced it, exercised a beneficial influence on some other species. In this way it was explained that several crops of the same kind would not grow successively on the same field, because the excrementitious substances left in the soil by the growth of these crops were present in too large a quantity to admit of the further healthy growth of the same crop; by a similar process of reasoning, the ground was believed to be in a favourable condition for the growth of some other family of plants that could appropriate and flourish upon these particular compounds.

This notion, although very popular some time ago, is altogether a theoretical fantasy, as no direct evidence exists even of the formation of these excrementitious matters in the soil by plants, far less of their taking any part in the development of the succeeding crop. The more probable cause of this inability of the soil to produce many satisfactory crops of the same sort is explained by the facts before stated in connection with the composition of the ash of plants. It will be recollected that the ash of a particular tribe of plants always has the same approximate composition, and that while the number of ash constituents of plants seldom varies in the different groups, their amount and relative proportion differ with nearly every variety of vegetable produce. Further, it will be remembered that, in each kind of plant, some one or two ash constituents predominate, which will obviously be removed from the soil in largest quantity by the growth of the particular kind of plant or crop to which they belong. Hence we can easily understand that a soil which has just suffered a heavy drain upon one or two of its constituents for the development of a particular crop, will be unable to furnish the additional quantity of the same materials requisite for the healthy growth of a second crop of the same kind; but, at the same time, its stock of other substances being comparatively undiminished, it is fully capable of responding to the demands of some other order of plants that is satisfied with a different set of materials. In the same manner several crops of different kinds may successively flourish on land where a second crop of the same description would utterly fail; but where the same crop, or one of a similar nature, is repeated, even after an interval occupied by intervening crops, the soil will be equally unable to supply it with a due amount of material, unless it has been replenished by the addition of manure, or unless the interval has been long enough to admit of the formation of sufficient soluble and wholesome materials, from the insoluble and otherwise useless ones locked up in the fragments of undecomposed rock which most soils contain, or by the effect of capillary action, etc., in obtaining supplies from the subsoil.

In support of the latter view we have the strongest evidence in the fact that similar crops may be satisfactorily grown upon land, time after time, if a suitable proportion of its constituents is maintained, and other details of careful cultivation attended to. In addition to the influence exerted in this way by mineral matters, we must bear in mind that some crops stand in need of a more readily available store of nitrogen than others.

But apart from the character of the materials a crop extracts from the soil during its growth, its place in a series of crops, or in a rotation, is regulated by the capabilities and habits of the plants composing it ; it being well known that different kinds of plants are very unlike in their ability to seek their food from the soil and provide for themselves ; some varieties are helpless, so to speak, and languish for want of food, unless it is placed immediately within their reach. Others, again, are indefatigable and industrious in shifting for themselves even under difficulties, and if food is at all to be had, they will search out and appropriate it. These latter plants are highly useful for collecting together the small quantities of valuable materials scattered throughout a large bulk of soil. We may distinguish these as industrious plants, since they are noted for sending out roots to comparatively great depths and distances in the soil in search of the compounds required for the fabrication of the seeds and other parts of their structure at the surface. To this tribe of plants belong the clovers and grasses ; hence the improvement in the surface-soil that may be effected by laying it down in grass, and the advantage that is gained by the introduction of a grass-crop in the series of a rotation. This advantage will of course be in addition to that gained by the accumulation of nitrogen from the atmosphere brought about by these plants, much of which is retained in the soil after their removal, by the roots and other *débris*. Amongst this group of plants sainfoin is conspicuous, and is highly valued in districts where thin soils overlie porous limestone rock, as on the Cotswold Hills. This plant possesses in a high degree the power of thrusting its roots to great distances, and collecting and bringing to the surface the small quantities of fertilizing materials these rocks generally contain. The surface-soil is thus enriched, and becomes better adapted for the growth of those plants above noticed, which, from the rapidity of their development, or for other reasons, are unfitted to search for their own food. Examples of this latter kind of plants are the turnip, swede, and other root-crops. It is well known that these crops will not flourish unless a copious supply of fertilizing materials is immediately within their reach; and as the substance these plants most require, especially at the early periods of their growth, is phosphoric acid, we can account for the fact that superphosphate of lime (a manure particularly rich in phosphoric acid) is so efficacious in promoting the growth of root-crops. For the same reason, the superiority of well-rotted farmyard manure, compared with that in a fresh condition, is mainly due to the larger amount of available phosphoric acid it contains. On these, and other circumstances, the rotation proper for a particular kind of soil is founded, and the foregoing remarks are intended to explain a few of the general laws which regulate the order of the crops of a series.

NATURAL RENOVATION OF EXHAUSTED SOILS.

It will now be proper to inquire into the means by which the soil is replenished with the materials removed from it by culture. It is known that a soil wholly or in part exhausted will, if left to itself, in course of time recover its fertility. This effect may be traced to several causes, amongst which the following may be mentioned :—We have seen that several bodies exist in the soil, as oxide of iron, alumina, humus, etc., which possess the power of absorbing and fixing the ammonia from the air. Again, combinations of the same valuable fertilizing material are continually brought down by the rain and stored up in the clay and earth of our fields. The ammonia collected in this manner, although extremely small in quantity, must not be overlooked in considering the natural restoration of the soil (page 56). By the growth of natural herbage, the surface-soil becomes enriched by the accumulation of organic matter derived from water and the atmosphere, and by the same means any valuable mineral substance existing in the lower regions of the soil will be brought to the surface and distributed through this organic matter. The loss by drainage of valuable plant-food will of course also be reduced. Even during the ordinary systems of cultivation, when the greater part of the produce is carried from the land, the amount of organic matter in the soil in most cases increases, because many plants produce even a larger amount of organic material, in the shape of roots, under the surface, than they do above it, in the shape of leaves, seeds, or other kinds of produce. Hence, when such plants die, all this organic matter is left in the soil, and tends to its improvement, not so much through any direct effect it exerts on the growth of succeeding generations of plants, as by mellowing and loosening the texture of the soil. On the decay of organic matter in the soil, all the mineral substances it contains are separated in a finely-divided state, and distributed through a porous mass that the roots of living plants can easily penetrate, and upon which they eagerly feed, the nitrogen present also becoming available by the formation of nitrates. Another and very important cause of the natural renovation of the fertility of land must now be noticed. In describing the mineral constituents of the soil, we have several times had occasion to advert to the fact that the same mineral substances which in a soluble and available form constitute its mineral fertilizing materials, also occur in most soils as stony and insoluble combinations, which take no part in assisting the growth of plants ; and it has been remarked that the fertility of a soil depends not so much on the presence of certain compounds, as upon the condition in which these compounds occur. By the unceasing action of the weather, these insoluble and useless compounds are slowly converted into combinations that will admit of conveyance to the organs of plants ; thus, by exposure to the wind, frost, and rain, these soluble fertilizing substances steadily increase and accumulate. To these causes is chiefly to be ascribed the restoration of land when left to itself for a length of time, as in the ancient system of long fallows.

The principal object sought to be obtained by the operations of draining, ploughing, exposure to frost, harrowing, cultivating, etc., is to hasten and accelerate the action of natural agents in these processes of replenishing the soil.

In many soils, especially the better sorts of clay land, the quantity of certain fertilizing materials in this locked-up state is very great—in fact, for generations to come, inexhaustible. Hence the chief business of the cultivator of these soils consists in the employment of the above-mentioned mechanical means for assisting Nature in setting free, and rendering available, these hidden treasures ; and the application of manures—at least of general manures—becomes a secondary object. But in all soils the above-named mechanical operations constitute an important division of the labour of the farmer, and must in all cases precede the more direct improvement of the soil by the application of manures.

Although the above-mentioned processes may be conveniently considered under the head of " mechanical operations", yet their effects depend to a considerable extent on chemical changes, which we must trace in order to understand their action. Another series of operations, including the application of manures, may be described under the head of "chemical means" of improving the soil. As a preliminary step to entering upon these divisions of our subject, it will be proper to make ourselves acquainted with the distinguishing characters of fertile and barren soils. In order to understand clearly the chemical and mechanical differences between productive and unproductive land, let us first observe the composition of some examples of known fertility.

EXAMPLES OF FERTILE SOILS.

	No. 1. A loamy soil remarkable for producing fine crops of wheat.	No. 2. A rich vegetable mould.
Silica	66.19	72.70
Peroxide of iron	4.87	6.30
Alumina	14.04	9.30
Lime	.83	1.01
Magnesia	1.02	.21
Potash	.80	.10
Soda	.43	
Sulphuric acid	.09	.17
Phosphoric acid	.24	.13
Organic matter	8.55	10.08
Water	2.94	
	100.00	100.00

These analyses were made when it was unusual to determine the nitrogen in soils, for this reason the percentage is not given; examples in which it is shown will be found on page 97.

FERTILE SOILS.

By the above analyses we learn that in these soils, which may be accepted as standards of fertility, the sand, clay, organic matter, and other more bulky constituents are so proportioned that neither prevails to an excessive amount. Again, the more valuable mineral constituents—phosphoric acid, sulphuric acid, potash, etc.—are found in appreciable quantity, while no substance likely to injure or retard vegetation is present. A fertile soil also possesses many qualities regarding which chemical analysis gives us no information.

The chief of these properties is its texture. A certain looseness, uniformity, or mellowness, extending to a considerable depth from the surface, is requisite to entitle a soil to the appellation of the term "fertile". However abundant and complete the chemical constituents of a soil may be, unless these ingredients are intimately mixed and finely divided, it will still require improvement to raise it to its maximum fertility.

Infertile and Barren Soils.

In proportion as the mechanical or chemical qualities of a soil are remote from those above named, so will it be an infertile or a barren one. The sterility of land may be owing to a variety of causes. While many soils are hopelessly infertile, from the obvious reason that they are too thin and poor ; others, again, equally worthless in practice, present external characters so false that a stranger would be apt to pronounce them to belong to the better class of soils.

We may conveniently consider sterile and deficient soils under three heads. First, those whose sterility is caused by the presence of some substance deleterious to vegetation, or to an excessive quantity of some otherwise useful material ; secondly, those in which the absence of necessary food-constituents of plants is the immediate cause of their inferiority ; and, lastly, soils infertile because their mechanical texture is bad. Amongst the inferior soils belonging to the first of these divisions are those soils occasionally met with whose infertility is due to the presence of ferrous sulphate, described in a preceding chapter. It will be remembered that on another page we referred to the results of some experiments, which appear to show this salt to possess under some conditions a certain manurial value ; this, however, in no way interferes with the remarks made here concerning its undesirability as a normal constituent of soils. It is not uncommon for this substance to exist in the subsoil, and not in the surface-soil. In this case its effects are displayed only upon certain deep-rooted plants, which are found to languish and die as soon as the roots come within the influence of this compound. Peaty and boggy soils belong to this class, as in these cases the excessive quantity of vegetable remains is the immediate cause of infertility, which need to undergo oxidation before the useful elements they contain become available. Coupled with this defect, and in most cases the primary cause of it, is the presence of stagnant water. This of itself constitutes a source of infertility. Hence wet, undrained, cold soils must also be included in this division.

To the second group of infertile soils belong those that have been exhausted by injudicious cultivation : these may still retain a fine mechanical texture, their chemical health only being impaired. Soils that are deficient in substance, as those that are too thin and shallow, must also be considered as belonging to this class ; while soils of the third kind are those whose mechanical texture unfits them for supporting the healthy growth of plants. They may be too close, heavy, and retentive, as in clay soils, or too loose and porous, as in sandy soils. Soils of the former description frequently occur, containing in abundance all the materials required for the vigorous growth of every sort of crop, and require only mechanical improvement to convert them into land of superior character. Such may be called crude soils.

EXAMPLES OF BARREN SOILS.

	No. 1. A barren sandy soil.	No. 2. A peaty sterile soil.
Silica and sand	96.00	7.96
Alumina	.50	.63
Oxide of iron	2.00	.12
Lime	.01	.55
Magnesia	trace	.08
Potash	—	.01 (Potash and Soda)
Soda	—	
Phosphoric acid	—	.02
Sulphuric acid	—	.19
Chlorine	—	—
Organic matter	1.49	90.44
	100.00	100.00

We will now proceed to consider the means at our command for removing or ameliorating the above-named general causes of infertility, by which we accelerate or assist those provided by Nature already mentioned. Some of these means will also constitute a necessary department in the cultivation of all soils.

Mechanical Means of Improving the Land.—Draining.

Of these mechanical operations, draining is undoubtedly the most important, since, apart from the fact of an excess of water being a common source of infertility, an efficient means of drainage may be regarded as an indispensable condition in all cultivated soils ; and this in many instances can only be attained by artificial drainage. In some land the natural drainage is too active, and constitutes a serious defect, as in sandy, porous soils. In most cases, however, the reverse of this state of things exists, and nothing can be done with the soil until an artificial system of removing the water is established. This is especially the case in clay soils, which, as we all know, are exceedingly retentive of moisture. In these, and to a less extent in soils of other characters, the water that falls in the shape of rain, or that drains from higher ground, accumulates and stagnates, and seriously interferes with the growth of plants, unless an effective outlet is provided. When no means of egress for the water exist, a morass or bog is formed and the soil becomes entirely unproductive. When the arrangements for the escape of water are defective, a corresponding reduction of fertility ensues ; and although the surface-soil may not apparently be suffering from an excess of moisture, it often happens that the subsoil is permanently soaked with stagnant water, which greatly retards the healthy formation of plants. Thus, like many other good things, water—which, as we have seen, is so essential in every stage of the development of vegetation —becomes, when present in excessive quantity, altogether injurious. The evil effects of too much water in the soil may to some extent be explained as follows.

The soil in a healthy condition consists of a layer of loose, open material, full of cavities and pores, through which the atmospheric air and the gases produced by the decay of organic matter continually circulate. The air is indispensable in the soil to enable the functions of growth to proceed and new supplies of fertilizing material to be prepared. If, as in the case of undrained land, these cavities and pores of the soil are filled with water instead of air, it is clear none of these necessary changes can proceed; indeed, it is considered that, under such circumstances, instead of oxidation taking place, the reverse process occurs, which may involve an appreciable loss in the case of any nitrates present. Further, in the presence of stagnant water, all sorts of unnatural compounds are formed in the soil, which more or less interfere with the growth of plants and the health of animals. The proper circulation of the air through a soil is in a measure dependent on the means of exit that exist for water. When a shower of rain falls on properly drained ground, the rain, upon penetrating into it, drives out the inclosed air, to occupy its place; but, on the cessation of the rain, as the water continues to sink into and through the soil, it is followed by a new supply of fresh air, which in its turn acts upon the vegetable and mineral substances present; and thus the process of decay and consequent production of fertilizing material proceeds with renewed vigour.

Moreover, the clay and other substances of the soil are capable of extracting from rain-water the small quantities of fertilizing materials which, as already noticed, it generally contains. When a shower of rain sinks through the ground, most of the substances the rain-water holds in solution are retained and ultimately appropriated by the roots of plants; but when the soil is already saturated with water, as in undrained land, no passage, or only a limited one, through the soil can be found by the rain; it therefore merely runs off the surface, and these valuable constituents are wasted.

Wet, undrained lands are also sometimes called "cold" soils. This is a very proper name for them, since soils that contain an undue quantity of water are actually colder than they would otherwise be. This is explained by the facts noticed in a previous chapter in describing the properties of steam. It will be remembered that steam, whether natural or artificial, always contains a large quantity of heat, and that the evaporation of water, or its conversion into vapour, is always attended by a loss of heat. Thus the heat of the sun shining upon wet ground is wasted by the evaporation of a portion of the water, which, in becoming steam, absorbs the heat that would otherwise be retained in the soil, and the latter being deprived of a proper amount of warmth, vegetation is retarded. Moreover, in the vapour thus given off from stagnant water soaking in earth, all kinds of poisonous gases, etc., are present. The miasma of warm climates, and the milder forms of it in temperate ones, that give rise to agues and fevers so common in countries where drainage is altogether neglected, are emanations of this kind. Anyone may satisfy himself of the production of noxious vapours from stagnant water under these circumstances by mixing any earth with water in an open vessel, and allowing the mixture to stand for three or four weeks: during this period the materials will have acquired an offensive odour.

Thus, by the process of draining, the soil is rendered more porous, open, and looser; all its cavities and interstices, formerly occupied by stagnant water, are now filled with sweet air, busily employed in promoting a healthy decay of the vegetable and mineral substances that it contains, and converting them into wholesome food for plants. The earth is thus mellowed, enriched, and in every way better suited for the purposes of agriculture. By draining, the soil is also made deeper; a greater depth of earth will be penetrated by the roots of the plants growing upon it, and an additional increase of produce on this account may be looked for.

Since by draining the land is made warmer, and the crops growing upon it hastened in their growth and brought sooner to perfection, the draining of a district produces a change tantamount to an improvement of climate—it becomes drier, warmer, and also more wholesome and healthy to its inhabitants.

Another important effect of draining is in hastening the drying of soils after wet weather. As every farmer knows, the land must be in a proper state of dryness before any kind of work upon it can be attempted; and however inconvenient or expensive a delay may be, this condition of the soil must be waited for. Anxiety from this cause is often felt in wet autumns, when prolonged rainy weather interferes with the sowing of the wheat-crop. It may be well once again to mention the fact that in such weather, at this season, the loss by drainage of soluble plant-food from unoccupied land will be great. This applies, of course, more particularly to nitrates, the production of which during the warm months being, as we know, especially abundant; hence efficient measures should be taken to prevent this waste of valuable materials by means previously referred to.

Land that is properly drained is, of course, much less subject to remain in this wet, unmanageable condition than undrained or imperfectly-drained soil; and as in the former case the proper condition of dryness during the intervals of wet weather is sooner reached, an opportunity will often be afforded for carrying on the necessary operations of the season; while land of the same kind, but undrained, remains in a state wholly unfit to be touched, and some other course of procedure than the one intended has to be adopted, even though at inconvenience and loss.

A further effect of draining must now be noticed, viz., the assistance it affords to all manuring materials. Manures, of whatever sort, can be more economically applied on drained than on undrained land; in other words, the same quantity of manure will go farther, or produce better results, on moderately dry ground than on that which is wet and undrained. We can easily understand the reason of this: it is only what we should expect on recollecting that most kinds of manure, like organic matter and other substances provided by Nature in the soil, require to be more or less altered by the atmosphere, etc., before they can exert any useful effect; and as the quantity of air present in an undrained soil is very limited, it is not surprising that manures should require a longer time to act, and appear less satisfactory than in better-constituted soil. Moreover, we are now aware that most fertilizing materials act upon plants through the medium of water; the water, or moisture of the ground, dissolves small quantities of certain mineral substances and conveys them to the roots of the plant. We have already noticed that the acid sap of the roots themselves is largely instrumental in rendering soluble those compounds of value to the plant which water is unable to dissolve. But in order that water may perform the office properly, it must circulate or move through the soil in different directions. During rain, the water falling on the surface will gradually pass downwards through the land. Again, during hot, fine weather, the evaporation from the moist surface will impart an upward tendency to the moisture in the soil; but, in whichever direction the moisture moves, it will evidently carry with it small quantities of the manuring materials it has dissolved from the fragments of those substances occurring at different points of its course; and being everywhere intercepted by the roots of plants, it yields to these delicate organs as much of the materials it has gathered as they are inclined to make use of. But in undrained land, where the water of the soil is more or less stagnant, or incapable of circulation, the fragments of manuring substances become enclosed in a layer of saturated material, and all those particles not immediately adjacent to the roots of the plants take no part in contributing to the growth of the crop, and for the time being are useless.

From these observations we may infer that draining is the first and most important means at our disposal for the improvement of all descriptions of land in which an undue proportion of water prevails. It merits this distinction not only on account of the numerous beneficial changes it effects in the texture of the soil, but also because it is almost indispensable as a preliminary step to the employment of other more direct fertilizing agents. All the resources of scientific agriculture will be useless unless a proper amount only of water is maintained in the soil, and the removal of every quantity beyond this is provided for. This end, as before remarked, can generally only be secured by artificial drainage.

Ploughing.

The mechanical operations of ploughing, subsoiling, trenching, etc., can only be employed to greatest advantage after proper drainage has been secured.

Ploughing, besides the more immediate effect of breaking up and loosening the earth, exerts a secondary effect, by exposing to the action of the weather a greater surface of the soil than would otherwise be the case. This effect of ploughing is strikingly displayed in winter fallows. The action of frost in reducing the soil to a state of division, far beyond anything we can produce by artificial means, is well known; and since on a flat surface of land the effects of frost would be but small, in consequence of the short distance to which frost usually penetrates, a much greater advantage may be gained from its effect by ploughing up the ground in autumn, and in this condition leaving it exposed to the action of the weather. By this plan masses of earth and clay will be exposed on all sides to the frost, and become frozen through their bulk. In this process the moisture they contain, on being converted into ice, expands, and thus forces and holds apart every particle of earth in their constitution. On the return of warmer weather the ice again becomes fluid, and once more assumes its original bulk, while the separated particles of earth now crumble down to a beautifully light porous mass, which in a high degree promotes the absorption of ammonia and other fertilizing constituents of the atmosphere.

Deep Ploughing, Subsoiling, Trenching, Etc.

The principal effect of ploughing is to break up and loosen the soil, so that the air, which, as we have seen, is so necessary to a fertile and healthy condition, may freely penetrate through it in every direction. The roots of plants will generally only descend so far from the surface as this loosening by the plough extends. The depth to which the plough can be used will, of course, in a great measure, be regulated by the natural thickness of the soil; but, in many cases, no reason exists why this natural depth should not be extended, and the soil deepened by encroaching on the subsoil. On some kinds of land great improvement has been effected by this means.

To this end deep ploughing and subsoil ploughing are employed. By these operations the deeper regions of the soil are loosened, and will now admit of penetration by the roots of certain deep-rooted plants; at the same time the drainage of the surface-soil is still further promoted, and its wholesome porosity maintained. The most useful effect of these operations consists in furnishing the soil with a new store of fertilizing materials, which the lower portions of many descriptions contain, either belonging to them naturally, or that have been washed into them by the continued action of rain and other agents, which constantly tend to bury all materials added to the surface-soil. The recovery of these buried treasures is still further assisted by the gradual admixture of the subsoil with the surface-soil, as in trenching and allied operations.

The striking effects often seen to follow the adoption of trenching and deep ploughing, in increasing the produce of districts where the use of these operations had previously been unknown, may be traced principally to this cause. The valuable material removed from the surface-soil during many generations is again brought into use, and acts with renewed vigour in promoting the growth of plants. Moreover, the deeper layers of soil, that have hitherto remained undisturbed, often contain valuable mineral constituents, which, when mellowed by exposure to the atmosphere, greatly add to the fertility and productiveness of the upper portions.

After ploughing, we naturally arrive at the allied operations of harrowing, cultivating, rolling, cleaning, etc. By these auxiliary means the necessary looseness and well-mixed condition of the soil is more completely attained: by the same operations the ground is cleaned, or freed from those inveterate enemies to the farmer, the weeds, or those plants that are too ready to grow. These may of course serve a useful purpose by retaining constituents of the soil which would otherwise be lost. But clearly it is wiser to obtain this advantage without the drawbacks that accompany weeds by the aid of rapidly growing green crops. When, however, land is very foul, it is certainly advisable to burn the weeds collected in cleaning it, particularly when couch-grass abounds. By this means they are effectually prevented from again taking root and distributing their seeds, while at the same time their ashes become valuable additions to the fertilizing materials of the soil. But naturally their nitrogen is lost, for which reason the course we have just indicated of ploughing in or feeding some green crop is much to be preferred when circumstances admit of its adoption.

While speaking of weeds, we feel it desirable to mention that deep ploughing is not unattended with a certain amount of risk, for the subsoil may possess characteristics which we should by no means wish to bring to the surface, or the seeds of charlock and other weeds may exist there in abundance, and consequently flourish when brought under favourable conditions by this means of cultivation. We must not, however, on this account jump to the conclusion that the practice is undesirable, and therefore better avoided, but should try the effect first on an experimental scale if we have any misgivings about the result. The more completely these operations of pulverizing, mixing, and cleaning the soil are carried out, the finer will be the growth of the following crop, and the smaller the quantity of manure it will require to raise this crop to perfection. As before stated, all artificial manures go further on a soil that is well cultivated than on one that is full of coarse lumps, and is carelessly mixed and cleaned. We can easily imagine that this should be the case. A given bulk of earth in a soil that is well prepared will admit of a greater number of roots and fibres penetrating through its substance than when the same space is occupied by coarse, unbroken clods, as in a carelessly-prepared soil. The special importance of these considerations will become more evident if we bear in mind how largely the nourishment of plants is dependent upon the fine hairs or fibres of their roots, whose search for food will manifestly be much helped or hindered by the condition of our land. In the former case every portion of the soil adjacent to the plants of a crop will be intermingled with roots, which will make use of all the fragments of manuring material within their reach; and thus every portion of the manure added will take part in supplying the growing crop: whereas, in the latter case, a great part of the manure applied gets beyond the reach of the roots, and in this isolated position is for the time being useless. Moreover, the substances supplied in the shape of manure to certain crops—as, for instance, phosphatic manures for root-crops—are required by the plants *during the* *early stages of their growth*; and unless these materials are within reach of the tender roots at this early period, much of the good effect expected from the manure will not be forthcoming: a point of special importance, when we are anxious to promote their rapid growth that they may be able to outstrip the ravages of any of their numerous enemies. Thus, although even in an imperfectly-prepared soil the manure applied may ultimately be reached by the roots of the plants, yet at this more advanced period of their growth it will be of much less use to them than if available earlier.

Intermediate in character between the mechanical and chemical means of improving the land are some important operations, which must now be briefly considered: these are, mixing, paring and burning, liming, marling, etc. While, on the one hand, the texture of the soil is considerably altered by the bulky nature of the materials concerned in these operations, an equally important effect is often produced by the chemical action of some of them.

Mixing of Soils.

Much improvement may often be effected in the texture of a soil by adding to it those kinds of earth it seems to be most deficient in; for instance, a heavy clay soil will obviously be improved by the addition of sand or any other loose and porous material. Again, sandy soils require only clay to overcome their chief failing—viz., their want of retentiveness; while, on thin, scanty soils, the addition of earthy matter of almost any description will effect improvement by adding to their depth and substance. In most cases, economical considerations present insurmountable obstacles to the improvement of soils by these means. At the same time it must be admitted that in many situations, where the requisite materials are at hand, immense improvement might be effected, and at an outlay for which the increased produce of the land may reasonably be expected to pay a good interest. Beds of sand are often found underlying the stratum of clay on which the soil rests. Again, deposits of clay are often accessible in districts where sandy soils prevail: in cases of this sort, the spare labour of horses and men may be profitably expended in thus adding useful material to the defective land. The addition of clay to a soil deficient in this substance not only improves its mechanical condition, but greatly adds to its fertility, in virtue of the numerous useful qualities before mentioned as belonging to it. As we have already mentioned on page 70, the addition of humus is also of the greatest value to soils in which it is lacking.

Paring and Burning.

These operations are perhaps not so frequently recommended as formerly; this refers more particularly to the latter, for, as our readers will have learnt from an earlier page, it is attended with the serious drawback that it involves a complete loss of the nitrogen present in soil subjected to the process; and, even in cases where the proportion of organic matter is excessive, the remedy is sometimes found worse than the disease; others also consider the phosphoric acid compounds are rendered more insoluble by this treatment. The combination in which they occur has probably a great deal to do with this point; nevertheless, under certain circumstances, although the means are doubtless rather violent, there are advantages connected with this method which must prevent us from entirely discarding it. These operations may be valuable in heavy, clay land, where every practicable means of increasing the looseness and porosity of the soil is to be eagerly sought for. Sometimes also they can be employed with advantage on lighter soils, since, in virtue of the chemical action of the burned materials, an amount of fertilizing substance, equal to that imparted by a good dressing of manure, is often added to the soil by the adoption of this plan.

This applies to certain elements of plant-food only, and is doubtless owing to the formation of more soluble compounds subsequently referred to.

The operations of paring and burning are not always connected : it is most profitable in some cases to burn clay by some sort of cheap artificial fuel ; and as the burned clay is always the more effective material, we will first inquire into the changes clay and earth undergo in the process of burning. We must again call attention to the fact that all soils, more especially clays, contain a great deal of fertilizing materials in a crude, undecomposed state —a form that cannot be made use of by plants. It has also been stated that, by the slow action of the rain, frost, and other atmospherical phenomena, these insoluble substances are gradually rendered soluble and converted into a form that can be made use of by plants. The same changes can be effected more rapidly by fire. As in the case of organic matter, the same alterations that take place by long exposure to the air at ordinary temperatures during the process of decay are produced almost instantaneously at a high temperature, or, in common language, by fire ; so, in a less degree, with these mineral constituents of the soil, fire is capable of performing in a short time what is slowly effected by long exposure to the action of the atmosphere. When clay is burned at a very high temperature in a furnace or kiln, it partially melts, and becomes a vitreous hard mass, which on cooling retains any form that may have been given to it before burning, and is almost imperishable by the weather. On this property of clay depends its application in the art of pottery, or the manufacture of useful domestic articles of crockery-ware. But when clay is burned at a lower temperature, as when we burn it in heaps with coal-dust or vegetable matter, its physical properties are altered to a less extent, and it becomes a porous friable substance, that easily crumbles to powder on exposure to the air. This burned clay differs from unburned, in having lost its plasticity, or that property of adhering and sticking together when wet. In this burned condition it remains in a powdery state, even when soaked with water, and in this respect partakes of the character of sand. On this mechanical property depends its value as a means of lightening and imparting porosity to heavy, clay soils; but in its chemical qualities it also differs widely either from unburned clay or that which has been fused at a high temperature. Under the latter conditions but very little of the constituents of clay can be dissolved by water; whereas, in that which has been properly burned at a low temperature, many of its components are rendered soluble in water, and others are so changed in constitution that by exposure to the air they readily become soluble, and at once capable of furnishing food for plants. On this chemical property of burned clay a considerable share of its usefulness is based.

In the operation of paring and burning a quantity of organic matter, as we have seen, is destroyed: this consists of vegetable remains, stems and roots of plants, with perceptible quantities of animal matter in the shape of the larvæ and bodies of insects, etc. With regard to the latter we here have another reason for considering burning a useful process at times on land infested with pests of the kind; this is probably one of the most efficient ways of destroying them. We cannot well touch upon this point without referring to the interesting fact mentioned by Miss Ormerod that the extreme character of the weather last winter was not successful in killing these larvæ. In certain kinds of soils the organic matter accumulates too rapidly, and attains an objectionable proportion. Its decomposition must therefore be brought about; still under most circumstances burning would hardly seem advisable in these cases. Again, the operation of paring and burning may be resorted to on foul pastures, or land full of roots and weeds, which often resist all other means of destruction. Obviously in some of these instances the destruction of organic matter must be regarded as a secondary consideration, and, even when this material is of a less objectionable kind, its sacrifice for some of the useful effects of burning must occasionally be allowed. In the case of weeds or inferior grasses, much benefit will result to the soil from their destruction by fire should they resist milder treatment; since these plants, like their cultivated brethren, remove from the soil useful mineral substances. The soil is thus impoverished to supply the useless plants. When burned, however, all the mineral substances they have consumed are recovered, and returned to the land in a condition that can at once be appropriated by cultivated plants. Thus the ash obtained by paring and burning consists of a mixture of burned clay and earth with the mineral constituents of the vegetable matter used in the process; and with respect to these ingredients constitutes a valuable manure especially useful for root-crops.

Liming.

The use of lime is justly esteemed as one of the best means we possess for improving certain kinds of land. On many soils the addition of lime is followed by increased fertility, and in numerous cases the improvement effected in this manner is so striking that we cannot wonder at liming being at present ranked amongst the standard operations of agriculture.

We have remarked on a former occasion that lime is required for the growth of all kinds of cultivated plants, and, consequently, is an indispensable constituent of all fertile soils; but, while lime is invariably present in soils that admit of cultivation, the quantity naturally contained in them is often very small, and especially too small for the vigorous growth of certain crops. Hence the addition of lime to soils of this description must obviously increase their fertility. It is on land of this kind that the most striking effects of lime are displayed, especially when, as is not unfrequently the case, a soil contains in abundance all the materials required for the growth of plants, with the exception of this one. In these cases, the addition of lime is all that is necessary to transform a comparatively barren soil into one of superior quality. To a less extent, the use of this substance on ordinary soils is generally attended by good effects; and even on lime soils, that contain a large proportion of calcareous material, the use of lime of some other sort, or from some other district, is frequently beneficial. Hence we find that lime acts in the soil in several capacities.

It not only acts as a direct manure, by increasing the supply of a material necessary for the growth of nearly all plants, but it provides us with one of the best means of altering the condition of substances already present in the soil, either by destroying or modifying any that are objectionable and noxious, or by the conversion of indifferent bodies into useful fertilizing materials, which properties are the chief causes of its value, for while not open to the objection attached to burning, equally desirable results may often be obtained in a far more satisfactory manner. For instance, a soil whose fertility is impaired by an excessive quantity of vegetable matter, as peaty or boggy land, may be relieved of this encumbrance by a copious dose of quick-lime. We have already described the properties of lime, and it will be remembered that it, like all alkaline or caustic substances, possesses the property of rotting and destroying organic matter of every sort. Hence, when added to soils of this description, it quickly diminishes the quantity of insoluble vegetable remains. In speaking of the properties of humus, and other organic matters of the soil, we alluded to the well-known fact that vegetable remains, under peculiar circumstances, refuse to decay, and accumulate to an injurious extent. This kind of vegetable matter, popularly known as "sour humus", is generally found in undrained, or but imperfectly drained, land. To remove this sour humus, lime is frequently employed, which, by acting upon the insoluble vegetable matter, hastens its decay, and is said to "sweeten" the land ; as by decay these materials furnish carbon dioxide and other compounds useful to plants. Suitable conditions are also thus obtained for the formation of the all-important nitrates. The lime thus converts a noxious ingredient into a source of fertility. Again, in the case of soils that are infested with insects, a dose of lime is the least troublesome and most effective remedy.

One of the most useful effects of lime seems to depend on the changes it brings about in the mineral constituents of the soil, as in the last-described operation of burning the decomposition of the various minerals of the ground is accelerated, and silica, potash, and other useful food-constituents of plants set free.

In considering the agricultural value of lime, we must not forget its mechanical effect on the soil. When applied in large quantities to clay lands, it opens and loosens the dense masses of clay, and imparts a certain amount of porosity and mellowness ; and while so doing opens the way to further improvement by exposing a larger extent of surface to the action of the atmosphere.

Thus we perceive the changes that can be brought about in the soil by the addition of lime are numerous and important, and in some measure account for the high value attached by many persons to this substance as a manure.

The effects of lime in the soil, as above briefly enumerated, are most actively exhibited when in a caustic or freshly-burned state ; but also in a less degree by that in other conditions. Whenever practicable, it is advisable to apply the lime in the state of hydrate, or as slaked lime, care being taken that it is not applied in such quantity as to overdo its work. We have already described the chemical properties of lime, and the changes it undergoes by burning and slaking. It will be remembered that one of the effects of these operations is to reduce the lime to a fine state of division, so that, apart from the superior chemical effects of slaked lime, by using it in this condition we gain a further advantage, through its peculiar mechanical form, which admits of intimate admixture with the soil, and thus secures the fullest effect that lime is capable of imparting. When using lime in this condition it is generally brought to the field in a caustic or hot state, and put up in small heaps, loosely covered with earth. In the course of two or three weeks the lime is completely slaked and falls to powder, which can now be easily spread over the land.

The quantity of lime applied to the land in this manner will, of course, vary with the purpose it is intended to serve. If employed for a special object—as, for instance, to remove the excess of organic matter from old pastures when broken up—a copious dressing will be necessary; but where the soil has become deficient in lime, and an additional quantity is added, to act as a direct manure, a much smaller quantity suffices. Much difference of opinion exists amongst practical men as to the best system of liming the land. While some persons recommend a large application at long intervals, others again think it better to use a smaller quantity more frequently. Theoretically, we should think that, provided no special reasons exist to the contrary, small portions at short periods would be the better system for obtaining the most satisfactory effect; since it is well known that everything applied to the land exhibits a tendency to sink in the ground, and bury itself beyond the reach of the plants. But even these short intervals can be but comparatively so, as the most useful action of lime is exhibited only under circumstances necessarily not of frequent occurrence. The following table exhibits the quantities of lime applied in different districts :—

QUANTITY OF LIME APPLIED PER IMPERIAL ACRE IN DIFFERENT DISTRICTS.

	Bushels.		Years.	Bushels in a Year.	When applied.
Roxburgh	200	every	19	or 10½	To the fallows
Ayr (Kyle)	40	,,	5	,, 8	Ditto, ditto or lea
Carse of Stirling	50	,,	6	,, 9	ditto
South Durham	90	,,	12	,, 8½	ditto
Worcester	70	,,	6 or 8	,, 10	Before grasses and tares

It is found in practice that different sorts of lime act very differently when applied to the soil ; in other words, the lime produced from one kind of limestone will be found to produce superior effects to that obtained from another source, although, perhaps, this latter contains quite as much real lime as the former. Hence it is clear that the increased fertility following the application of lime to the land is not always entirely due to the actual lime it contains. Moreover, the fact above referred to—viz., that on certain soils resting on limestone formation, and containing abundance of this material, the addition of lime of some other sort is often highly beneficial—compels us to seek for some different explanation from that afforded by the known effects of real or pure lime.

We must bear in mind that the lime produced from any natural source is not, chemically speaking, pure lime, but a mixture of the pure compound with certain foreign matters in greater or less abundance. These foreign substances are found to materially influence the effects of a particular kind of lime, and often account for its superior or inferior quality. Of these impurities of limestone the more common are sand, oxide of iron, alumina, maguesia, etc., which to some extent affect the value of the lime made from it ; but the agricultural value of limestone is chiefly regulated by other materials, generally present in much smaller quantities ; indeed, in quantities so small, that until comparatively lately they were altogether overlooked. Amongst these we may mention phosphoric acid, sulphuric acid, the alkalies potash and soda, etc. As these substances are all more or less valuable fertilizing materials, we can no longer wonder that a limestone containing small yet appreciable quantities of them should produce a lime that exercises a better effect on the soil than a purer variety free from these materials ; and it must be remembered that, although the quantity of these more precious substances is small compared with the bulk of lime employed, yet, as large quantities of the latter are often added to the land, the absolute amount of the above-named fertilizing materials will be considerable, and often equal to that contained in a dressing of farmyard manure. We annex some analyses of two or three well-known varieties of agricultural limestones.

COMPOSITION OF LIMESTONES USED FOR AGRICULTURAL PURPOSES.

	Great Oolite or Bath-stone.	Cornbrash.	Mountain Limestone.
Carbonate of lime	95.34	89.19	96.35
Magnesia	.73	.77	2.28
Oxide of iron and alumina	1.42	2.98	.67
Phosphoric acid	.12	.18	—
Equal to bone-earth	(.26)	(.36)	—
Sulphate of lime or gypsum	.20	.24	—
Soluble silica	1.01	1.23 }	.70
Insoluble sand, etc.	1.18	5.41 }	
	100.00	100.00	100.00

In using lime as a manure, it must not be supposed that other manures can therefore be dispensed with. Lime is a special manure, and performs in the soil an office of its own sufficiently important to entitle it to a high place amongst manures ; at the same time, it ought never to be used in place of farmyard manure. It is quite true that on certain fertile soils the addition of lime without any other manure is all that is necessary to insure abundant crops ; and from this fact we might naturally infer, as many farmers have inferred, that lime is a substitute for other fertilizers. But this is a grievous error. Lime, by its stimulating effect on the land, will for a time replace manure, by exciting the soil to supply sufficient material for the growth of several successive crops ; but this supply is effected at the expense of the strength of the soil ; it is drawing upon its capital, and must sooner or later suffer for this undue exhaustion.

On the other hand, the opinion entertained by some farmers of the exhaustive effects of lime in all cases, and that therefore it ought not to be employed, is equally erroneous. The fact is, no ill effects are likely to follow the use of this material, provided other kinds of manure are supplied in proportion : it is from neglect of this principle that most of the failures experienced in the use of lime are to be attributed. Lime ought never to be applied at the same time with other manures ; it is advisable to put off the application of the latter as long as possible to land that has been recently limed. This precaution is the more necessary in the case of manures that contain salts of ammonia ; since, as we have seen, lime liberates ammonia with the greatest ease from all its combinations. Hence the simultaneous application of lime and farmyard manure would probably be attended with a considerable loss of fertilizing material. No fear of loss need be entertained from this property of lime after it has been exposed in the soil for two or three months, as by this time all the caustic lime will have become carbonate of lime, and have lost its more active properties.

Marl, Chalk, Shell-sand, Etc.

It is not always expedient or practicable to apply lime to the soil in a caustic or burned state : in these cases other forms of the compound must be resorted to, as marl, chalk, shell-sand, and even limestone rock. All these materials act in a similar manner to burned lime, but in a less vigorous degree, and at a much slower rate. Moreover, these substances are found to vary in composition, and consequently in their agricultural value, even more than limestones. Marls especially are found of all degrees of fitness for use as manures, some of them being particularly rich in fertilizing constituents. The mechanical form and condition of marls greatly add to their value as means of improving the soil ; but as the number and varieties of calcareous mixtures, locally called marls, are very great, it is quite impossible for us to enter into any details respecting them. The value of all these materials, apart from that due to the lime they contain, will generally depend on the proportion of phosphoric acid, the alkalies, and other essential mineral food-constituents of plants ; and, in conclusion, we may remark that their agricultural value can in most cases be ascertained by chemical analysis.

COMPOSITION OF A FEW CALCAREOUS MATERIALS USED IN AGRICULTURE.

	Chalk.		A Marl of the West of England.	Shell-sand from Cornwall.
	Lower.	Upper.		
Clay and insoluble matter ...	2.04	1.46	22.80	12.60
Carbonate of lime	96.51	97.20	73.80	81.08
Oxide of iron and alumina ...	.55	1.05	.78	1.68
Magnesia	.25	.06	.82	3.17
Phosphoric acid	.07	.04	.26	.23
Sulphuric acid	.31	—	1.54	.93
Potash	.08	.17 }	trace	.31
Soda	.19	.02 }		
	100.00	100.00	100.00	100.00

CHAPTER IX.

CHEMICAL MEANS OF IMPROVING THE LAND.

SECTION I.—FARMYARD MANURE, ETC.

OF the operations hitherto described, the greater number are in most cases employed as preliminary steps to the more direct improvement of the soil by the application of manures; and as the action of the various manures is essentially chemical, although a mechanical effect may in some cases be exerted in a minor degree, they may conveniently be considered under the above title, which also includes all those operations by which some essential change is effected in the composition of the soil; some of these operations we are already acquainted with—as, for instance, liming, paring, burning, etc. We have now, therefore, to consider the very important subject of manures.

The application of manures consists for the most part of putting back into the soil an equivalent for what has been taken from it in the shape of cultivated produce. But this is not all we can do by means of manures: we can also add more material, and other materials, than the soil already possesses; and thus, by altering its constitution, endow it with new qualities and capabilities, so as greatly to increase its productiveness. If a soil is naturally deficient in some material required for the development of a particular crop, this crop cannot be successfully cultivated; but if we add the requisite component, the soil will now be capable of producing the desired crop. It often happens that land possessing most of the characters of fertility is yet defective, from an insufficient quantity of one or two essential constituents; by adding these substances, and thus increasing their proportion in the soil, the defect is at once overcome, and the quality of the land greatly improved.

Amongst the soils usually met with, few can be called complete soils, or are capable of producing several kinds of crops with equal degrees of vigour and abundance ; in most cases, the land is naturally best fitted for the growth of a particular family of plants, which is often indicated by the wild vegetation that flourishes upon it. This unequal capability of soils is dependent on the proportions of their constituents ; and, generally speaking, the species of plants that most delight to grow on a particular kind of soil contain mineral constituents whose relative abundance corresponds with that of the components of the soil in which they are found to flourish, and which we may therefore fairly conclude is most favourable to their growth.

For this reason, each kind of soil commonly met with favours the growth of a particular crop, or is better adapted for raising one kind of produce than another. For instance, clay soils will produce abundant crops of wheat, while they are scarcely capable of yielding a good crop of turnips ; turnips, again, will flourish in lighter soils, that are less suited for wheat ; while lime soils are particularly favourable to the growth of leguminous plants ; as clover, peas, etc. A complete soil, on the contrary, is one that will produce with almost equal luxuriance every kind of cultivated crop. In a soil of this kind the constituents are so proportioned that neither of them abounds to so great an extent as to interfere with the vigorous growth of any kind of plant, while, at the same time, every material required by each cultivated group is present in sufficient quantity to produce a satisfactory yield. A soil of this description may be called a perfect one; and were all of this desirable character, the farmer might raise his corn and rear his cattle with as much ease as some persons ignorant of agricultural pursuits seem to imagine ; but, as most of us know, land of this kind is seldom met with in practice. The character of the soils usually available to farmers is in most cases remote from these qualities, and careful management is required to raise from them sufficient produce to pay expenses of cultivation. It is, however, the object of an advanced system of agriculture to alter and improve these defective soils, to extend their capabilities, and increase their productiveness. This can only be accomplished by perseverance in the employment of suitable mechanical means of improvement, and in the judicious application of manures.

In theory, we may convert any defective soil into a fertile and complete one by the addition, in proper quantities, of those materials it is deficient in ; and, on a small scale, we may carry out this theory in practice. For instance, we may make a garden on any kind of soil, and, by the addition of proper materials, soon prepare a fertile mould, capable of producing in luxuriance every kind of plant of whose growth the climate will permit. But in practice on a large scale, as on the land of our farms, the case is very different. The alteration we can effect in the character of the land in this manner is limited by considerations of *£ s. d.* ; the question in these cases is, not what can be done, but what can be done to pay. The extent of soil in our fields being so vast, tons of material being required to produce the least appreciable change in its composition, alteration to the same extent as in the case above referred to becomes wholly impracticable. At the same time we must remember that, by a prolonged course of skilful cultivation, immense improvement may be effected, and has been effected, in several parts of this country and elsewhere.

Since the term Manure, in the sense usually understood, includes a great number of different substances, most dissimilar in their properties and the influence they exert on the land, it will be proper to adopt some system of classification, in considering this most important division of Agricultural Chemistry. Farmyard manure, superphosphate of lime, soot, lime, marl, etc., are all called manures ; yet the effects which these materials severally exercise on the soil are widely different—the only property they possess in common being, that they are all more or less useful in promoting the growth of plants. We will consider these materials under two heads:—1st. Those substances provided by Nature as manures. These will chiefly consist of the solid and fluid excrements of animals, or a mixture of these with vegetable substances, as used in farmyard manure. 2nd. All those materials known as artificial manures; as bone-dust, superphosphate of lime, guano, nitrate of soda, etc. Amongst these we shall also include refuse materials; as wool-refuse, gas-liquor, etc. Manures may further be divided into two other classes—1st, those called general manures, which add to the general fertility of the land, as farmyard dung, and other mixtures; and 2nd, those manures which act only on particular crops, or are used to perform some special purpose in the soil. Hence they are called special manures; such are lime, gypsum, nitrate of soda, sulphate of ammonia, etc.

In the present first section we have decided to consider the question of farmyard manure, since this material is still more largely used than any other for the purpose; also sewage and similar manures.

From the earliest periods of the history of agriculture to the present time, the material most employed for imparting fertility to the land has been the mixture of the solid and liquid excrements of domestic animals and various kinds of litter, known as "muck" or "dung"; and even in our own day, when the art of tilling the soil has attained a high degree of excellence, and involves the use of numerous artificial manures—of whose powers exaggerated notions are frequently entertained by uninitiated persons—the old-fashioned and bulky material, dung, still occupies, as we have said, the first place amongst manures. This must necessarily be the case, because farmyard manure is the natural source, and the most economical one, on which the farmer must rely for sustaining the fertility of his land.

In speaking of the products of vegetable growth, we remarked that the food of animals consists of mixtures of the vegetable principles called woody fibre, starch, sugar, gluten, and other compounds, prepared by plants for the nourishment of the former ; and that when these mixtures are received into the bodies of animals, some of the above compounds they contain are, as we have seen, consumed in the production of animal heat and force, and are commonly known as "heat-giving" principles; while a lesser and choicer portion furnishes the material required in building up and renewing the tissues, muscles, etc., of the body. Hence, these compounds are included under the general term of "flesh-forming" materials. When the constituents of this latter kind have performed their appointed office—have taken their share in supporting the functions of animal life—they are in their turn dismissed from the position they had occupied in the system and now seek to return to the condition in which they existed before being manufactured by the plant. In other words, the flesh-forming materials of the food having become part of the flesh of the animal, are again removed (in consequence of the unceasing process of decay and renewal common to all grades of life), and finally are expelled from the system in the solid and liquid excrements. These substances consist of the same ultimate constituents as the food from which they have been formed, but differently arranged, or, generally speaking, merely grouped together in simpler combinations or smaller parties. The solid excrements also contain the undigested portions of the food with other solids, that cannot be disposed of by any other means. So far from this matter being repulsive, as imagined by some fastidious persons, it displays to us, when viewed philosophically, the beautiful circle of operations necessary to the existence of animal and vegetable life.

Thus we may conclude that all the materials of the food consumed by an animal are again returned either to the atmosphere through its lungs, in the breath, or, with the exception of a small quantity carried off by the skin, to the earth, in the shape of the solid and fluid excrements.

The urine of animals is by far the more valuable portion of their excrements. It generally contains the greater part of the nitrogen originally present in their food. It will be remembered that the nourishing power of food is in a great measure dependent on the amount of nitrogen it contains. This is because this element is the more essential constituent of the nourishing principles of food. The same standard can be applied to a large class of manuring substances. In these cases the value of the manure, or the food of the plant, is also dependent on the amount of nitrogen it contains; because, by decay and oxidation in the soil, this nitrogen will be converted into nitrates—a class of compounds, it will be remembered, that forms feeding-material of the greatest value to plants. For this reason the urine of animals is a most valuable manuring substance, far more valuable than the solid excrements, which contain much less nitrogen. On the same principle that we are too often regardless of the pernicious substances we may inhale with our breath, because they are invisible, so, in a smaller degree, we think less of the fluid manure at our disposal, because it presents so much less to our sight than the more bulky, but far less important, solid dung. Every care should be taken by the farmer to preserve the urine of his cattle from waste, since, in addition to the valuable properties it possesses, in virtue of the nitrogen contained, other materials, highly useful as fertilizing agents, are present. The nitrogen occurring in urine exists in several different combinations, called by chemists urea, uric acid, hippuric acid, etc.; but these compounds are all so far alike, that by spontaneous decay all the nitrogen they contain separates in the form of ammonium carbonate, which escapes into the air, unless measures be taken to prevent its doing so. It is from this source that the ammonia always present in the atmosphere of stables, as noticed in a former chapter, is derived. The urine of the horses that is not absorbed by litter, is quickly decomposed, and evolves the salt of ammonia just referred to. Of course, the ammonia, liberated in this manner, is obtained at the expense of the manure produced in stables; and although a considerable proportion of this ammonia may be recovered by the methods noticed in speaking of the properties of this valuable source of nitrogen, yet, however efficient these means may be, a portion of it will always escape and be lost. Reference has already been made to the useful properties possessed by gypsum, sulphuric acid, and superphosphate, in preventing this loss; earth may also be used with advantage, and instead of employing straw as litter, for which purpose it is not very well adapted on account of its small effect as an absorbent, peat has been introduced, especially into London stables, with considerable advantage: a result we should have anticipated, as it readily absorbs liquids. The smaller loss of ammonia which takes place is one, amongst other reasons, why the manure produced by feeding cattle in boxes is superior to that prepared in any other way. By this system the urine is completely retained in the litter, and little of its nitrogen wasted either by drainage or separation into volatile ammonia. As we shall presently learn, the ammonia produced by the splitting up of urine does not escape when this decomposition proceeds in the substance of a mass of solid manure and litter, as in a dung-heap. It is only when exposed alone in its fluid condition that its fermentation is attended by any considerable loss of ammonia. In addition to the compounds of nitrogen above described, which all yield by decomposition the valuable ammonia, other compounds of mineral origin, and nearly as valuable, are also present in urine. The properties of phosphorus and its combinations, as fertilizing materials, have already been noticed; and it was remarked, that the value of these compounds is greater when they occur in a form that is soluble in water. In urine a large proportion of these soluble compounds of phosphorus exists; indeed, it was from this source that phosphorus was first prepared. Hence, on this account alone, it should be highly prized as a manuring material. Again, potash, with other mineral substances of more or less fertilizing value, are also present in considerable proportion. In urine these solids are dissolved in a large quantity of water, and for this reason cannot be recognized by our unaided senses. In order that an idea may be formed of the composition of urine, we subjoin analyses of that of the more common domestic animals.

APPROXIMATE COMPOSITION OF THE URINE OF THE

	Horse.	Cow.	Sheep.	Pig.
Water	890	920	865	975
Organic matter, urea, uric acid, etc. ...	80	60	99	15
Containing nitrogen, capable of yielding of ammonia	(16.)	(9.)	(17)	(4.)
Inorganic matter, salts of potash, soda, etc.	30	20	36	10
Containing phosphoric acid	1.20)	(.7)	(.48)	(1.25)
	1000	1000	1000	1000

By the above analyses it will be seen that the composition of the urine of different animals varies exceedingly ; at the same time, it must be understood that the composition of that of animals of the same kind is by no means constant, being subject to variation from a number of causes ; as, for instance, from age, sex, the quality and quantity of food consumed, condition of the animals, etc. The foregoing results may, however, be accepted as fair approximations to the average composition of the urine of each of the species of animals named.

The solid excrements are made up of those portions of the diet unfit for assimilation ; consisting for the most part of woody fibre, as well as of other insoluble materials of the food that can only be removed from the system through this channel. The composition of the solid excrements of different kinds of animals varies to a still greater extent than that of the urine above described ; moreover, the mechanical form of these substances materially influences their agricultural value, as it is on this circumstance that the facility with which they undergo decay chiefly depends, and consequently by which their fitness for particular purposes is regulated. The average composition of the solid excrements of our domestic animals may be thus stated :—

APPROXIMATE COMPOSITION OF THE SOLID EXCREMENTS OF THE

	Horse.	Cow.	Sheep.	Pig.
Water	760	840	580	800
Organic matter, woody portions of food, and other insoluble matter ...	210	136	360	170
Containing nitrogen, capable of yielding of ammonia	(6.10)	(3.6)	(9.02)	(.73)
Mineral substances, consisting of insoluble salts of food	30	25	60	30
Containing phosphoric acid	(3.48)	(2.25)	(6.2	(4.5)
	1000	1000	1000	1000

Of these materials, in a fresh condition, but a small proportion is soluble in water ; for this reason they are less valuable than the liquid urine. Again, they contain less nitrogen, and the mineral fertilizing elements are not so abundant as in urine. By exposure to the air and moisture, these substances enter into putrefaction, and liberate the nitrogen they contain as ammonia ; at the same time their other constituents become of greater manurial value, as they are rendered more soluble by this action ; hence these solid matters increase in usefulness after fermentation or incipient decay, provided this fermentation takes place in a manner that prevents the escape of ammonia liberated during the process. We also find in the solid excrements substances that are absent, or nearly so, in the urine—as, for instance, lime, magnesia, silica, etc.; and as these compounds, like the more valuable phosphoric acid, ammonia, etc., must be regarded as indispensable for the healthy growth of plants, we perceive that the solid and liquid excrements of animals are best adapted and evidently intended to be used together as a manure : the one portion containing what is deficient in the other, while united they contain every material required as food by vegetation. When both of these substances are present, distributed through a porous mass of vegetable material, as straw or other litter, they constitute the mixture known as farmyard manure—the most complete, most valuable, and only perfect manure. Whatever assistance the farmer may derive from the use of artificial manures, he should rely chiefly on his farmyard manure for supporting the fertility of his land, since this substance only can return to the ground all the materials removed from it by cultivation. From the number of its constituents, and their naturally favourable arrangement, together with the peculiar mechanical condition in which they occur, and its low price, we are justified in considering farmyard manure as the most valuable of all fertilizing materials, and superior to any artificial mixture that we can obtain at the same cost. Persons unacquainted with agricultural chemistry or with practical farming are apt to form extravagant notions of the power of artificial manures ; they seem to think that by the use of a small quantity of odourless, cleanly, dry powder, the more bulky and, to them, offensive farmyard manure may be dispensed with. It need scarcely be said that such is not the case—no amount of artificial manure, however skilfully mixed and prepared, can ever imitate farmyard manure, or be used in its place. At the same time it must be recollected that, in the hands of skilful farmers, artificial manures are valuable, nay, at the present time, indispensable additions to farmyard manure for the growth of certain crops ; but, generally speaking, as before observed, these substances will be of minor importance, and the chief resource on which the farmer must depend for the growth of his crops and obtaining fodder for rearing his cattle will be farmyard manure : although the reverse procedure is sometimes fcund desirable.

In the production and management of this important material great errors are often made, and corresponding losses incurred by farmers. Many men, thoroughly practical in other respects, do not understand the management of farmyard manure, and have yet something to learn in this department of agriculture. That this should be so is an illustration of the length of time required to make well-ascertained facts understood, or for the principle of saving money in the long run by means of a little present expenditure to be put into practice. In these days we must also consider another factor, which is, that although a farmer may be fully alive to the truth and importance of these facts, he cannot adopt them because ready money is not forthcoming. When this book first appeared the chemical principles involved in the management of farmyard manure had been but recently made out, yet even now, after the lapse of a considerable number of years, we feel we should not be justified in omitting the remarks as to the want of understanding which exists regarding the production of this material. Until a short time before the date referred to above, little was known concerning the changes farmyard manure undergoes during fermentation, and still less of the relative merits of the different modes in use for the preparation of this important requisite.

This matter is now thoroughly explained, and the chemical changes involved in the operations clearly made out; while the extent to which these changes are regulated in different systems of management has been rigorously determined.

This important investigation was conducted by the late Dr. Voelcker, an account of which, together with its results, appeared in the *Journal of the Royal Agricultural Society*, wherein he does the author the favour of recognising his assistance. This investigation, carried out by means of practical experiments on a large scale, as well as by the more delicate operations of refined chemical analysis, will no doubt confer great benefit on the agricultural community, and cannot fail to be duly appreciated by everyone who is interested in the progress of agriculture.

In the carrying out of this research in the laboratory of the Royal Agricultural College, the author enjoys the honour of having contributed a part, and is therefore in a position to speak confidently and from personal experience on the facts adduced in the following description of the changes farmyard manure undergoes by keeping; and it is hoped that this description may not be unworthy of the attention of practical men, who may, we think, gather from it hints that will be of service to them in the treatment of this source of plant-food.

Farmyard manure, consisting of the solid and liquid excrements of horses, cows, and pigs, mingled with some material used as litter, is found to be a mixture of most uncertain composition. This absence of uniformity arises from the fact that this product is exposed to variation from many sources, the more prominent of which may be thus enumerated :—1. The quantity and quality of the food supplied to the animals that produce it. 2. The relative number of animals of one species that take part in its production. 3. The age of these animals. 4. Their breed and condition. 5. The quantity and quality of litter used in the manufacture of the manure. On account of these circumstances scarcely two samples of farmyard manure can be found alike, yet on any one farm where a particular system of feeding and management is followed, the manure produced will be tolerably uniform; and all samples of farmyard manure, wherever and however produced, are so far alike that the following general remarks will apply with equal force in every case. An average sample of fresh farmyard manure, or long dung, was found to consist of :—

GENERAL COMPOSITION OF FRESH LONG DUNG (COMPOSED OF HORSE, COW, AND PIG DUNG).

	In Natural State.
Water	66 17
*Soluble organic matter	2.48
Soluble inorganic matter	1.54
†Insoluble organic matter	25 76
Insoluble inorganic matter	4.05
	100.00
*Containing nitrogen	.149
Equal to ammonia	.181
†Containing nitrogen	.494
Equal to ammonia	.599
Total percentage of nitrogen	.643
Equal to ammonia	.780

Or, to be more precise, in 100 lbs. of the material were found :—

COMPOSITION OF FRESH FARMYARD MANURE (COMPOSED OF HORSE, PIG, AND COW DUNG, ABOUT FOURTEEN DAYS OLD).

Detailed Composition of Manure in Natural State.

Water		66.17
*Soluble organic matter		2.48
Soluble inorganic matter (ash) :—		
Soluble silica	.237	
Phosphate of lime	.299	
Lime	.066	
Magnesia	.011	
Potash	.573	
Soda	.051	
Chloride of sodium	.030	
Sulphuric acid	.055	
Carbonic acid and loss	.218	
		1.54
†Insoluble organic matter		25.76
Insoluble inorganic matter (ash) :—		
Soluble silica	.967	
Insoluble silica	.561	
Oxide of iron, alumina, with phosphates ...	.596	
Containing phosphoric acid	(.178)	
Equal to bone earth	(.386)	
Lime	1.120	
Magnesia	.143	
Potash	.099	
Soda	.019	
Sulphuric acid	.061	
Carbonic acid and loss	.484	
		4.05
		100.00
*Containing nitrogen	.149	
Equal to ammonia	.181	
†Containing nitrogen	.494	
Equal to ammonia	.599	
Whole manure contains ammonia in free state ...	.034	
" " " in form of salts	.088	

By an examination of the foregoing analysis we learn that fresh farmyard manure contains all the materials required for the growth of plants. Organic matter is present to supply carbonic acid and nitrogen, also mineral substances of every description that are in any way connected with vegetation ; phosphoric acid, potash, lime, soda, silica, all are present. It is chiefly for this reason that farmyard manure merits the title of the only complete manure. Yet by other qualities its claims to this distinction are still further supported, the principal of these being its mechanical form, the porous, bulky condition in which it usually occurs. As this quality is more prominent in fresh farmyard manure, recent dung is generally to be preferred for application to heavy clay land, where every means of loosening the soil is to be eagerly sought for. When applied in a fresh condition in autumn to soils of this description, it greatly assists the action of frost in mellowing and loosening their physical texture.

By the above analysis we also perceive that of the numerous substances which enter into the composition of fresh farmyard manure, but few are soluble in water, the greater number being undissolved by that liquid. We also notice that in many instances the same substance is present both in a soluble and insoluble condition.

As we are already aware, a substance must become soluble before it can be received into the organisation of plants. In this manner we can account for the well-known fact that fresh farmyard manure seldom exerts any immediate effect in promoting their growth. As we shall presently see, the principal transformation effected in dung by fermentation in masses or on decay in the soil, consists in rendering these insoluble matters soluble, in which condition only they are capable of exerting any beneficial action on crops.

We now state the composition of well-rotted manure or short dung. No alteration has been made in the arrangement of this and the preceding table, as it was thought better to retain the form adopted in the original paper. An average sample, about six months old, was found to consist of :—

COMPOSITION OF ROTTEN DUNG.

Detailed Composition of Manure in a Natural State.

Water		75.42
*Soluble organic matter		3.71
Soluble inorganic matter (ash):—		
Soluble silica	.254	
Phosphate of lime	.382	
Lime	.117	
Magnesia	.047	
Potash	.446	
Soda	.023	
Chloride of sodium	.037	
Sulphuric acid	.058	
Carbonic acid, and loss	.106	
		1.47
†Insoluble organic matter		12.82
Insoluble inorganic matter (ash):—		
Soluble silica	1.424	
Insoluble silica	1.010	
Oxides of iron and alumina, with phosphates ..	.947	
Containing phosphoric acid	(.274)	
Equal to bone earth	(.573)	
Lime	1.667	
Magnesia	.091	
Potash	.045	
Soda	.038	
Sulphuric acid	.063	
Carbonic acid, and loss	1.295	
		6.58
		100.00

*Containing nitrogen	.297
Equal to ammonia	.360
†Containing nitrogen	.309
Equal to ammonia	.375
Whole manure contains ammonia in free state	.046
" " in form of salts	.057

By this analysis we perceive that the components of well-rotted dung are the same as those of fresh; the difference between them being chiefly determined by the condition in which the constituents exist. The most striking variation is in the greater proportion of soluble materials present in rotten dung, notwithstanding the large quantity of water it generally contains. On further comparing the composition of the two kinds of manure, we notice that this increased solubility is especially apparent in the more valuable nitrogenous compounds, or those materials that yield by their decay ammonia. Again, a greater proportion of the precious phosphate of lime, or bone material, is present in a soluble state than in fresh dung. On acquaintance with these facts we can no longer wonder that well-rotted dung should be more immediately effective in promoting the growth of plants than in a fresh condition, as we now perceive it contains a much larger quantity of both their organic and mineral food, in a state that can at once be appropriated by the root-fibres. The dense and more compact condition of well-rotted manure also favours the rapid supply of its fertilizing constituents to the roots of plants ; since a larger quantity of it will be within the reach of these organs at one period. For this reason well-rotted dung is always to be preferred for application to root-crops. On the whole, we may conclude that well-rotted farmyard manure is more valuable than the same weight of fresh. The next question to consider is, what proportion of a given weight of fresh manure remains unaltered after the occurrence of fermentation in the heap ; in other words, how much, and what kind of material, is lost during the process of fermentation.

It has before been stated, that when animal or vegetable substances are removed from the influence of organized life, they spontaneously ferment, putrefy, or decay. In these natural processes the materials composing the organic matter undergo a series of changes, which terminate in their reconversion to the simple forms in which they originally existed before they became part of the organized structure.

We have instanced decay and putrefaction as operations analogous to combustion or the destruction of organic matter by fire ; in both cases the ultimate products are the same, and the heat that accompanies either process is in direct proportion to the rapidity of chemical action. We may therefore regard the operations of fermentation and decay as processes of slow combustion ; the only real difference between them and ordinary combustion being one of time : the final results in each case being, as we have seen, the same.

It has also been remarked that the readiness with which organic substances enter into decay is generally regulated by the number of materials of which they are composed. The more intricate their composition, the sooner they show symptoms of alteration. These preliminary remarks are necessary in order that we may understand the changes that take place during the fermentation of farmyard manure.

In the mixture of animal and vegetable compounds that we call farmyard manure, circumstances are generally favourable for inducing the early stages of decay commonly called fermentation, or more properly putrefaction. The complex materials of the urine are diffused through a moist, porous mass of substances exposing a large surface to the inclosed air. It is these compounds belonging to the urine that first enter into putrefaction, and, as matter undergoing such changes appears to possess the power of exciting a tendency to alteration in other and even more permanent compounds, fermentation soon becomes general through the mass.

This fermentation is the more active the warmer the weather, heat being in every case conducive to the alteration of organic matter: a certain amount of moisture is also necessary to the healthy fermentation of dung. If the manure is too dry, the operation is retarded, and a risk of considerable loss of nitrogen involved; while, by an excessive quantity of water, as when manure is allowed to soak in wet weather in yards, the process is entirely stopped. Under favourable circumstances, the fermentation of manure will steadily proceed until it assumes the compact form and dark colour of well-rotted or short dung.

During this process the manure is found to shrink much in bulk and lose a great deal of its weight. The questions naturally occur to us: Of what does this loss consist? And what becomes of it? In describing the destruction of organic matters by fire, it has been said that the greater portion of their substance passes off in the shape of carbonic acid gas and water; while the smaller quantity of nitrogen they contain is liberated in the shape of ammonia; and the ash or the mineral substances are left behind. The same remarks apply to the slower process of decay, the early stages of which we call fermentation or putrefaction.

During the fermentation of manure, a portion of th woody fibre of the straw and other non-nitrogenous com pounds is converted into carbonic acid and water, which fly off, while the larger part of these materials is changed into the black porous substance *humus*, before described as forming a part of the soil. This substance, or, to speak more correctly, mixture of substances, is always formed when vegetable matter suffers destruction by decay; and, as we shall presently learn, it performs an important part in the fermentation of farmyard manure. The dark colour of well-rotted dung is due to the presence of these compounds.

A great portion of the nitrogen contained in the nitrogenous compounds of the fresh manure is liberated in the form of ammonia—the volatile gas so often referred to as one of the most useful of fertilizing materials. One would naturally imagine that this substance, being volatile, would escape from the dung-heap during fermentation. A portion of it does escape, as may be proved by a simple experiment;* but the quantity of ammonia that disappears in this manner is exceedingly minute. The outcry often raised about the wasteful loss of ammonia by the fermentation of farmyard manure, and the necessity of employing chemical means for avoiding this loss, is based upon the supposition that *all* the ammonia liberated from the nitrogenous compounds of the manure escapes into the atmosphere; but

* Made by holding in the steam escaping from a fermenting dung-heap a strip of moistened red test-paper. This paper is dyed with a colouring matter which becomes red or blue upon exposure to the action of acids and alkalies respectively:—the fact of the red colour being turned to blue in this case proves the presence of ammonia, which is a strong alkali.

this is not the case. When fermentation is properly conducted, and the heap left as much as possible to itself, the ammonia liberated in the interior of the mass does *not* escape; or at least the quantity that does so—although sufficient to indicate the presence of this compound by the test above-named—is so small as to be altogether unworthy of notice in practice. However advisable it may be to employ chemical means for fixing the free ammonia given off by manure under particular circumstances, as in stables and in some other cases, nothing of the kind is requisite during the fermentation of dung-heaps. Nature provides means of fixing the ammonia simultaneously with its production. It is only in the hottest parts of the interior of the mass that ammonia is separated in a volatile state; and this, in its passage towards the surface through the exterior and cooler portion of the heap, is intercepted and retained by the humic acid and other allied compounds above noticed, which, as we have seen, possess in a high degree the power of fixing this base. And as a further provision against loss of ammonia, another substance having a great attraction for it, called gypsum, is also formed from the sulphur present in the manure.

The mineral constituents of the manure undergo no less important changes during the process of fermentation. The chief of these changes consists in their being rendered more soluble in water, with a consequent increase in their fertilizing value. The two more essential mineral constituents of plants are sulphur and phosphorus, since one or both of these substances are required in the production of the flesh-forming principles of food: these two bodies are also present in the fresh excrements of animals, combined in certain organic compounds. By putrefaction such compounds are broken up; and the sulphur and phosphorus are naturally found in new forms of combination; amongst which are two gases called respectively phosphuretted and sulphuretted hydrogen. These gases, together with other more intricate volatile compounds, fly off and give rise to the peculiar smell of fermenting dung. Only a minute amount of the sulphur and phosphorus escapes in this way ; the larger portion of them is found in the rotted dung, in the shape of compounds of phosphoric and sulphuric acids.

During the fermentation of dung the fluid portion sinks to the bottom of the mass, and drains away, while if, as is generally the case, the heap is exposed to the weather, every shower of rain that falls adds to this loss by washing out of the manure much soluble matter ; and since, by rotting, the manure becomes richer in these soluble materials, it is clear that unless some measures are taken to preserve these drainings, great loss is incurred from this source.

The above description of the changes farmyard manure undergoes by keeping applies to the early stages of decay known as fermentation, or more properly as putrefaction. When these periods are past, and the manure has become fully ripe, or has attained its maximum value, it should at once be made use of and added to the land ; since by longer keeping it becomes deteriorated, by undergoing further changes, and is soon weakened and unable to retain all its fertilizing materials.

From the preceding description of the fermentation of farmyard manure we gather the following facts :—

1. That the loss of substance sustained by farmyard manure during fermentation is caused by some of its constituents escaping into the air in the shape of gases, and by other fluid portions that drain away.

2. Those gases that escape into the atmosphere are comparatively of trifling value, since in most cases the plants to which the manure is afterwards applied will suffer but little deprivation from the absence of these volatile matters, which consist for the most part merely of water and carbonic acid gas.

3. On the contrary, that portion lost by drainage is the most valuable part of the manure, as it consists of ammonia,

potash, phosphoric acid, and other materials valuable to cultivated plants.

4. That ammonia, in any appreciable quantity, is not lost by escaping into the air, as is often supposed; but that it is retained in the heap in combination with certain organic acids, as humic acid, and other carbonaceous substances of the same kind, which are formed from the vegetable matter of the manure. That while this natural provision effectually prevents loss of ammonia by volatilization, no protection is afforded against loss by drainage; since many of these compounds are soluble in water.

5. That these natural means of fixing ammonia can only act when the fermentation proceeds undisturbed, so that the ammonia liberated in the interior and hotter portions of the mass may pass into the cooler and outer layers, where it can be retained; for this reason the turning of manure should be as much as possible avoided.

6. When the active fermentation of manure has ceased, no loss of ammonia will now follow exposure by turning; in fact, it may be spread over the land without fear of loss from this cause.

Finally, manure, when properly rotted, should be at once used, since its value diminishes by further keeping.

From a consideration of the foregoing statements we may arrive at the following general deductions.

The use of farmyard manure in a fresh condition, or as well-rotted dung, will depend on the means at our disposal, and the kind of land to which we intend to apply it. In the case of the soil being one of a heavy character, in which additional porosity and looseness will be advantageous, the best thing we can do when circumstances permit is to apply the fresh dung at once to the land; and if we cannot immediately plough it in, spread it over the surface. In doing this, no fears need be entertained of loss of fertilizing materials; on the contrary, by proceeding thus security from loss is almost insured, since in this disseminated state fermentation cannot proceed, and everything separated by drainage is received into the soil, where it is securely preserved until required by the following crops. In the application of dung to the land, the absorbent property of clay must be remembered. In speaking of the constituents of the soil, we mentioned as one of the properties of clay its power of retaining saline and other manuring substances, and preventing their removal from the soil by heavy rains. If our soil contains any moderate quantity of clay, we may avail ourselves of this property, and spread manure over our fields, and leave it in this state until we can conveniently plough it in, feeling assured that anything washed out of the manure by rain or dew will be stored up in the soil as safely as if the manure itself were buried. While in this condition no ammonia or any other volatile matter of material value will escape. Of course, we can only expect to adopt this course with satisfactory results for a reasonable length of time, as the organic nitrogen, in addition to the ammonium salts, becomes oxidised into nitric acid, the compounds of which we shall remember are easily lost in drainage water ; for this reason, therefore, we must not expect too much from the retaining power of our soils.

By at once adding manure in a fresh condition to our land, and afterwards ploughing it in, we secure all the vegetable matter which by fermentation is volatilized as carbonic acid gas. As before remarked, this loss in most cases is not worth caring about, because soils that have been under cultivation for any length of time generally contain enough organic matter of this description ; but on new ground, land containing but little humus, it may in some cases be advisable to avoid the loss of this vegetable matter. This can but be done by ploughing into the land the fresh or long dung.

If the soil is not of a character to benefit by the mechanical effect of long dung—or in cases where fresh dung is unfitted for the crop we intend to raise, as, for instance, a root-crop—

it becomes necessary to ferment the manure before application to the land. This operation is best conducted in well-constructed waterproof pits, provided with a sound tank for receiving the drainage. With this tank a pump should be connected, so that by suitable means the fluid drainings may from time to time be diffused throughout the fermenting manure. The question whether the manure-pit should be roofed in or not will depend on the character of the manure produced on the farm. If, as is the case in certain districts, an excessive quantity of straw has to be disposed of by conversion into manure, the latter will often be too dry to admit of a proper fermentation : hence exposure to rain will be beneficial. On the contrary, when litter is scarce, and the manure is naturally wet, all additional moisture from rain is to be carefully avoided. The most complete method of keeping manure seems to be in covered pits communicating with a tank, whence the requisite moisture can be supplied from the fluid drainings, and applied to the solid portion as required. In the construction of all receptacles of manure, especial care should be taken that proper waterproof linings be used, to prevent loss by drainage.

It has been shown that the loss of valuable material incurred during the fermentation of manure is chiefly from drainage ; for this reason manure-heaps should never be set up in situations where the drainings from them cannot be recovered. This fact cannot be too well remembered by practical men, who so frequently neglect taking any measures to avoid this source of loss, which is far more considerable than one would naturally suppose. No object is more common in agricultural districts than a manure-heap standing by the side of a lane, or on a piece of waste ground, where no provision whatever exists for collecting the fluid portion. The rich black drainings trickle away to a neighbouring ditch or pool, and often raise a fine crop of weeds, whose seeds being carried to the surrounding fields, produce an uninvited crop, for the destruction of which a further loss in labour has to be endured. These drainings that flow from dung-heaps may, without exaggeration, be called the essence of the manure. After heavy rains, the quantity of valuable material wasted in this way is very great, and consequently too much care cannot be taken to preserve the liquid part of manure ; and if no means exist for keeping this product in pits, it should at once be carted to the field where it is intended to be used, and, whenever practicable, at once spread over the land instead of setting it up in a heap at one corner ; but, where this is unavoidable, the surrounding earth should be heaped up, to absorb as much as possible of the drainings. The quantity of fertilizing materials that sink into the ground around and under a dung-heap is often pointed out to us by the increased luxuriance of the plants growing on the spot where, even some years before, such a heap stood.

When manure is spread over the land there is no necessity for immediately ploughing it in ; indeed, it is highly probable that, by not doing so, the soil is more evenly manured ; the soluble fertilizing materials contained in the manure are washed out by the rain and distributed more uniformly throughout the substance of the soil, and, as before remarked, on those that contain a fair proportion of clay no anxiety need be felt for loss of manuring substances by this course of procedure. On the contrary, in sandy, light, or hungry soils, that possess very little retentive power, the manure should be added in a well-rotted condition, and not be applied sooner than is absolutely necessary ; since every shower of rain will carry off a portion of the constituents intended for the crop. On soils of this description the best system of manuring seems to be the application of small but frequent dressings. As before noticed, it is chiefly for this reason that the system of liquid manuring succeeds best on light lands. We must not forget, however, that by using suitable means of increasing the humus in soils of this character we may render them far more serviceable.

With regard to the different systems of manufacturing manure by keeping the animals in boxes, stables, or yards, the first-named plan is undoubtedly the best for the production of manure, whatever objections of other kinds it may be open to. In box-feeding, the urine is better preserved and more intimately mixed with the solid excrements and litter, the whole being well incorporated and consolidated by the treading of the animal; moreover, the mixture undergoes a gentle fermentation throughout its bulk, which greatly adds to its future value. In sheds and stables a considerable portion of the urine is often wasted from the absence of effective drainage; and even where good drainage exists and the urine preserved, the manure produced in this way is generally inferior to that made in boxes.

The system of making manure in open yards is most wasteful and objectionable, particularly in cases where it receives the rainwater from adjacent roofs. It is not uncommon to see the drainage of a yard received by the pool that supplies the cattle with water, or rather the putrid fluid that had much better be called liquid manure.

This system of making manure is objectionable in every respect, perhaps chiefly on account of the facilities it affords for the deteriorating influence of rain, wind, and snow. By these agents the manure produced is gradually deprived of all valuable fertilizing materials it may contain, and soon becomes next to worthless. In an experiment made on a large scale in connection with the investigation before referred to, for ascertaining the relative merits of the different systems of preserving manure, it was found that manure spread in the usual manner over open yards exposed to the weather loses an enormous proportion of its useful constituents; and, as might be expected, the loss it sustains is the greater in those materials most important to plants.*

* A large quantity of manure was kept in a yard, in the manner usually followed in this system of feeding, and was examined at regular intervals.

After twelve months' exposure, it was found to contain but a trace of material that could furnish ammonia, and proportionately minute quantities of every other useful substance. Without entering into any details of this very interesting experiment, we may remark that after twelve months' exposure, two-thirds of the substance of the manure had been wasted, while the remaining portion was next to worthless, consisting for the most part of the woody matter of the straw used as litter. It seems desirable in this place to refer to the excellent practice of supplying animals fed upon our land with cake and other food from external sources. There can be no doubt of the usefulness of this means of increasing its fertility on account of the high manurial value possessed by foods of this character, which, however, of course varies in degree with their individual composition. By this means, also, we avoid the loss of plant-food through drainage from heaps, while the nature of the manure causes it to yield its nitrogen, phosphoric acid, etc., to the roots of crops in a thoroughly satisfactory manner. This matter has already been mentioned under "Cakes".

Town Sewage and similar Manures.

A few remarks on the sewage of towns and similar sources of manure may here be given, since these occupy a somewhat analogous position to the manure produced on a farm.

Very indistinct ideas are often held as to the value of sewage, and the loss incurred through its not being made more serviceable as manure. It is true the loss of fertilizing matter in this way from many large towns, and especially London, is really appalling from an economic point of view; indeed, it has been said by a good authority that it amounts to more than the whole production of chemical manures, the components of which are brought from all parts of the earth. But directly we inquire into the causes of the loss and the means at our command for preventing it, we are confronted with difficulties which up to the present may be said to have proved almost insuperable—at least, what has been done in the way of utilization is but a trifle compared with the amount still wasted, and, so far as London is concerned, with no prospect of anything different ; indeed, the worst feature in the case is the fact that we not only waste this enormous quantity of fertilizing matter, but require the expenditure of millions to do so.

Why this should be the case is difficult of explanation in the space at our disposal, and would seem to be not easy of comprehension even when gone into to the fullest extent, if we are to judge from the schemes brought forward from time to time for preparing portable manures from sewage at a profit, and on which much thought and money are lavished, but which are hopeless from the first. The chief causes of this may be summarised as follows :—

1. The most valuable constituent of excreta and sewage is the nitrogen. 2. This is found chiefly in the urine and liquid portion in a *soluble* form, as we pointed out in the introductory chapter while speaking of the changes undergone by oil-cake and other food when consumed by an animal. 3. It is not possible to recover this nitrogen again when mixed with much water, as is sewage, from the fact that none of the precipitants yet devised effect this object but to a very limited extent. They may clarify and purify it, or, in other words, remove the muddy appearance and offensive smell, and render it comparatively clear even so far as to allow of fish living in it ; but the nitrogen being soluble and not precipitable (except the little in the suspended organic matter), escapes, and is found in the clear liquid or effluent left on standing, and from which it is practically impossible to separate it again. To recall the illustration given in the new introduction, it would be more practicable to recover the gold from our sovereign if, after

dissolving, it were thrown into a tub of water, than to get back the nitrogen from sewage.

The sediment or sludge obtained from the precipitation of sewage contains a little of its nitrogen (the undigested portion of the food), and most of the phosphates, with the precipitant itself, and more or less earthy matter, the two first forming but a trifling percentage of the whole. This sludge is therefore of but slight value as manure, and very troublesome to deal with, from the difficulty of getting it into a manageable shape, owing to the large percentage of water it retains ; but even when dry, or partly so, its manurial value is so low that farmers will hardly take it at a gift. At the London sewage works it was found possible to get rid of much of the water by mixing with lime and pressing, when it was hoped the product would be of sufficient value to allow of it being utilized as manure ; but it was found, even when offered free of cost, that it was taken only to a small extent to form the basis of certain low-class manures—which will presently be referred to—and still remained an incumbrance. It is now, we believe, in its crude state carried out to sea in specially constructed vessels, and there discharged.

Hence it is only by irrigation that we can hope to do anything in the way of manure with sewage ; but even then some mode of precipitation is first requisite in order to remove its more offensive characters, and on sanitary grounds to allow of its fit application to crops, so that its nitrogen may be rendered unobjectionably available for plant-nourishment. We should add that on the smaller scale it is less difficult to deal with the sludge than as above, as it is found it will generally dry, if time is given, on slopes under cover, where sufficient space is at command, and disinfectants used if necessary. An ingenious scheme was propounded some years ago to burn this sludge and convert it into cement ; but it appears never to have been adopted on a practical scale.

Sewage farms have been established in various places and under proper management without creating any nuisance, and this appears to be the most promising mode of solving the problem of economic and unobjectionable sewage disposal, although the evidence as to their general success or otherwise appears at present somewhat conflicting. On the large scale, however, we believe it is claimed to be a success at Berlin, where the whole of the sewage of the city is dealt with, and, it would seem, even at a profit. There is no reason theoretically why this should not be true ; indeed, it is undoubtedly a reproach to our advanced science that this is not more generally the case, and if only this were so with the sewage of London, and many other large towns, the ratepayers would have good cause to rejoice. At all events, where an apparent success has been attained, every endeavour should be made through inquiry by authorised experts to ascertain whether it is really and truly so. And here it may be said that the disposal of crude sewage by discharging into the nearest river or stream is a worse than barbarous proceeding, and one altogether unworthy of any people making claims to scientific or sanitary eminence. Although the natural process of purification by oxidation doubtless protects us to a considerable extent, this is far too much relied upon, and recent researches in Bacteriology only confirm our instinctive feeling of disgust at having our natural water-supplies polluted in this manner.

The system of direct collection of excreta without the use of water is adopted to some extent, though attended with many difficulties, and from a manurial point of view is superior to removal as sewage. It is not, however, likely to extend, not so much on sanitary considerations as from its tendency to oppose our ideas of delicacy. It may be questioned whether the system of drainage by sewers does not entail as great evils as it is intended to prevent : there is the great drawback of bringing all the houses into communication through a common atmosphere in the drains, thus allowing of a wider dissemination of disease-germs. This is of course supposed to be obviated by efficient sanitary appliances ; but here, again, unfortunately, experts differ as to what arrangements are the best.

Earth closets afford an excellent resource in rural districts, and by allowing the product sufficient time the same earth may be used repeatedly, and all offence removed; at the same time a useful manure is obtained.

Night-soil, as collected in cesspools, is known to possess considerable merit as manure, and this arrangement is still largely in use in rural districts, being almost indispensable in country houses where water is used as a medium of removal, and if taken to a sufficient distance from the house, with a good system of traps, the plan is as good or better than sewers. Drainage of this sort is often conducted into the tank at farm buildings, or stables, but an instance is known to us in which a large amount of such drainage passed through faulty drains, and nothing ever reached the tank—a state of things which on porous soils we believe to be common. Again, the tank itself is often leaky, and allows its contents to escape into the adjacent sub-soil, from whence it too often finds its way into a neighbouring well. Many instances of contamination of water in this way have come before us.

In all the above modes of disposal there is a serious loss from a manurial point of view through the more or less incomplete preservation of the urine, which, from the fact of the nitrogen in it being soluble and invisible, as before pointed out, is too lightly valued as manure. Urine in its natural state contains 1¼ to 1½ of ammonia (nitrogen equal to) and about 88 water in 100 parts : this gives for the dry substance about 10½ to 12½ ammonia, and is about what we have found in a manure made experimentally from this source; the lowest figure being considerably above the present highest quality of guano. The loss of nitrogen from this source when allowed to run to waste, not to speak of the soluble phosphates (alkaline phosphate) before-mentioned, is really terrible, from an economic point of view, and the more so as the prevention of this loss is more practicable than in the case of sewage, since it might be collected from factories, railway stations, and many public places before admixture with water, as was formerly common on the small scale in the neighbourhood of certain cloth factories. Of course there is the difficulty of its offensive nature, but this is not greater than crude gas liquor, and if treated in the same manner in closed vessels, should yield satisfactory results, especially as it is sufficiently rich to allow of the use of absorbents for drying up, in the final stages.

When the price of nitrogen for agricultural purposes increases, as it is bound to do sooner or later as the population multiplies, and foreign supplies fall off, this question will certainly have to be dealt with. In concluding the subject we may mention that we have met with a great many manures at different times in connection with the supposed utilization of sewage by conversion into portable manures, but most of these have been disappointing, as our readers will have gathered from the foregoing remarks. A few, however, have proved exceptions, but in these the product obtained had mostly been "fortified" by the addition of phosphates and ammonia in some shape from other sources, and hence should more correctly be classed with ordinary artificial manures. This will be found the most promising mode of dealing with the sludge obtained from the precipitation of sewage, provided it can be dried without nuisance, and when the mixture can be sold at its real value in the locality, without the cost of railway carriage, it may possibly be disposed of to some advantage.

CHAPTER IX.—*Continued.*

Section II.—Artificial Manures.

Amongst the modern improvements in agriculture none are more striking than the mode and extent of manuring by artificial manures. Even within recent years the increase in the consumption of these articles has been very great, the output from some of the largest works having reached the enormous quantity of between 40,000 and 50,000 tons per annum; this fact, together with their still increasing employment, sufficiently testifies to their general efficiency in augmenting the natural productiveness of the soil: hence we must regard artificial manures not only as a valuable auxiliary to the cultivator of the land, but as a means which materially contributes to the general prosperity of the country by greatly increasing the home supplies of all kinds of agricultural produce.

Although guanos and other imported manures have been, on the whole, more largely used of late years, the extension above referred to has consisted in the main of a great development of the superphosphate manufacture, or the production of all those phosphatic manures prepared either from the various native and foreign mineral phosphates, or from these in conjunction with bone, bone-ash, etc., by means of sulphuric acid or oil of vitriol. The increase of late years in this branch of industry has been truly surprising, and has now reached an extent which could hardly have been dreamed of when the first attempts to reduce to practice, on the large scale, the valuable suggestion of Liebig to render bones more serviceable as manure by means of sulphuric acid, were struggling into existence against the prejudice which it is the fate of all innovations to encounter; while the still bolder efforts to render coprolites, or "pebbles", as they were jocularlv called, available in the same manner no doubt provoked a smile of incredulity from many a farmer who now applies to his fields, with a sound and well-founded belief in their efficiency, manures, prepared only more skilfully than formerly, from the same apparently unpromising materials.

In order that we may clearly understand the nature of artificial manures, their several properties, and in what they differ from farmyard manure, let us for a moment depreciate the latter, and point out its defects.

We find that, in so far as the chemical value of this mixture is concerned, it depends chiefly on the presence of three or four essential materials, and that these materials are distributed through a large bulk of comparatively useless substance; it is also rendered additionally cumbrous by the large quantity of water it contains: in round numbers, two-thirds of the weight of farmyard manure are water. On learning these facts, the question naturally occurs to us, Why cannot we prepare these essential materials in a separate or concentrated form? For instance, we learn that the most valuable constituent of farmyard manure is ammonia or other forms of nitrogen, but to get one pound of this substance we must take 137 lbs. of well-rotted farmyard manure. Again, phosphate of lime is a valuable constituent of dung; but 100 lbs. of dung contain only about 1 lb. of this substance. Why cannot ammonia or phosphate of lime at once be taken and added to the soil? In reply to these questions, it may be said that there is no reason whatever why we should not do this, if we can do so economically; in fact, this is what we endeavour to accomplish by making use of artificial manures. These substances may be regarded as the essential constituents of farmyard manure in a concentrated form. At the same time, it must be recollected that the less essential materials of farmyard manure—as soluble silica, magnesia, lime, etc.—although not so precious as the rarer substances above named, are yet necessary for the healthy growth of plants; and, even if we were so disposed, it is doubtful whether any artificial mixture we could prepare in imitation of farmyard manure would act so well as this substance in the soil; since the peculiar organic combinations of its constituents and the mechanical form of farmyard manure would be wanting.

It was in seeking replies to the above very natural questions that the value of artificial manuring substances was discovered. As soon as scientific men had clearly made out what materials are required by plants for their growth, and in tracing the sources of these materials had pointed out which were the more valuable constituents of manure, the notion of adding these substances from outside sources was readily conceived. The practice of adding artificial manures was, however, to some extent adopted before the principles on which they acted were understood. It was found, in certain cases, that the addition of some one substance to the land produced a better effect than could be obtained from farmyard manure. A striking example of the power of a special manure, and the unconscious adoption of a scientific principle, may be instanced in the pastures of certain parts of Cheshire. As is well known, these meadows, originally remarkable for their fertility and the richness of the cheese produced from them by continued pasturing, became impaired, and began to show symptoms of exhaustion, which could not be removed by the manure usually applied. It was found that the addition of bones to the soil produced the desired effect; the grass regained its accustomed sweetness and cheese-producing qualities. This restoration of the weakened pasture by the use of bones can now be easily explained, and will be adverted to in describing the composition of bone-dust.

In the same way, other substances have been found in practice to benefit certain crops, in a manner that could not be satisfactorily explained some years ago.

The more common difference between artificial manures and farmyard manure is the smaller number of constituents the former substances contain. While farmyard manure is composed, as we have seen, of a large number of materials—in fact, it contains all the fertilizing elements required in the growth of plants—artificial manures, on the contrary, contain but a few—often but one or two—of these elements.

A further difference may be thus stated: in farmyard manure the rarer and more precious fertilizing substances are scarce, and form but a small proportion of its bulk and weight, whereas artificial manures (that is, of the better sort) consist, for the greater part, of some or all of these more essential constituents.

The two more important classes of artificial manures are called respectively ammoniacal, or nitrogenous manures, and phosphatic manures. The first class consists of those in which ammonia, or what is nearly the same thing, combined nitrogen, is the prevailing constituent. To this class belong guano, nitrate of soda, sulphate of ammonia, soot, gas liquor, and animal refuse manures. By means of these manures we can supply to plants any quantity of ammonia that seems desirable; they are chiefly used as top dressings, for urging the growth of corn-crops in spring, although, in smaller quantities, useful for other purposes. The second class—the phosphatic manures—are those in which phosphoric acid is the chief ingredient, although other substances in less quantity are generally also present. Of these manures superphosphate is the principal; bone-dust and certain sorts of guano are also generally classed in this group. As we proceed we shall see that a great many valuable manures contain materials from both these classes, thus combining their advantages.

It is especially in respect to the utilisation of native and foreign mineral sources of phosphate of lime, such as South Carolina, Florida, coprolites of various kinds, Belgian, Somme, and other phosphates, that the greatest improvements of modern times have been made, as we shall presently point out, so that these materials now to a great extent supersede bone-dust, which was formerly thought to be the only legitimate phosphatic ingredient from which to prepare superphosphate and similar manures. Although bone-dust must still be considered an important raw material in connection with this class of manures, the prejudice, very prevalent in past years, in favour of its exclusive use, is, as we shall endeavour to show, not only erroneous, but calculated to lead to the disadvantage of those who act upon it. Bearing in mind the greatly increased demand for phosphatic manures of this description, consequent on their universally beneficial effects in the field, which would never otherwise have been met, and the reduction effected in their cost at the same time, with many other practical advantages which the command of these manures affords, we perceive that the means of rendering available for our present use the stores of phosphate of lime laid up by Nature for thousands of years in a mineral form, constitutes without doubt the greatest boon conferred by modern chemistry upon agriculture.

Again, the introduction of steam cultivation has given a further impetus to the employment of artificial manures, since the deeper and more perfect tillage thus attainable allows of a more liberal employment of them, with the certainty, under ordinary circumstances, of their yielding a proportionately increased return. This is especially the case on heavy clay soils, which, by the free use of suitable artificial manures, in conjunction with steam culture, may be brought to yield remarkably luxuriant and remunerative crops of corn; although it should be added that of late the tendency has been to return to horse traction. In other districts, also, the use of such manures for barley is now more widely extended; and notwithstanding the increased outlay thus entailed, the practice is found to pay, although it might have been regarded some years ago as at least venturesome.

The employment of artificial manures having thus gained additional importance in agriculture, and the number and variety of these articles, from which the farmer has to choose, having so greatly multiplied, it is probable that any information likely to effect a saving in their cost, while still preserving, or, if possible, increasing their practical efficacy, may not be unacceptable to the agriculturist, in whose annual business expenditure the cost of artificial manures forms in many cases a no inconsiderable item, or to others, concerned with agricultural improvement from less interested motives.

The general effects of the following artificial manures will be best understood by bearing in mind what has been said in the foregoing pages of the connection between the principal constituents of manures (which for simplicity we may here regard as phosphoric acid and nitrogen) and cultivated produce. Thus we have seen that the albuminous compounds of plants, or the flesh-forming principles of food, all contain nitrogen as their characteristic constituent in addition to the commoner organic elements—carbon, hydrogen, and oxygen. Again, phosphoric acid combined with bases forms a considerable proportion of the ash or mineral portion of all kinds of agricultural produce.

The constant removal of phosphoric acid and nitrogen from the soil by these means, especially the former, of course tends to lessen their amount, which even in the best of soils is but small ; hence the necessity for replacing them by means of nitrogenous and phosphatic manures. But by means of these manures we are enabled not only to replace what has been removed, but can, by adding more, increase their proportion, thus gaining a higher standard of fertility from which more productive crops may be calculated on.

The indirect effects of these elements of fertility are no less important : thus we may regard nitrogen as a key by which the natural stores of potash, etc., in the undecomposed minerals of the soil are unlocked and made available ; while by using phosphatic manures for our green crops we are enabled to gain supplies of nitrogen from atmospheric sources.

Nitrogen, phosphoric acid, and to a less extent potash, may thus be regarded as the more choice descriptions of plant-food, which the cultivator of the soil has to purchase to feed his crops, so to speak, in order that they may proceed vigorously with their work of organizing or building up the more abundant elements of food, everywhere present in the atmosphere and water. For we should not forget that by far the greater part of all food, whether of man or animals, is thus beneficently prepared from air and water through the instrumentality of plants, and upon which we are utterly dependent, since no chemistry of our own can produce even a blade of grass ; although, to quote the old saying, "it can make two blades grow where one grew before."

Since the various dissolved manures form perhaps the most important class, we shall now do well to direct our attention to them, and as a necessary preliminary step we will consider the composition of bones and other materials used in their production.

BONES, BONE MEAL, ETC.

The bones of animals differ from most other organic products by the large amount of mineral or earthy matter they contain. Organic matter of animal origin, like that produced in vegetable life, generally contains but a small proportion of mineral substances, seldom more than 2 or 3 per cent. of its weight ; but in bones we find a much greater proportion of earthy matter. In fact, nearly two-thirds of the weight of bones consists of mineral salts ; the remainder consists of animal matter, chiefly of the same description as that composing skin, gristle, etc., which when boiled becomes gelatine, with varying quantities of fat. When bones are strongly heated this animal matter burns away ; the gelatine being decomposed and yielding the nitrogen it contains in the form of ammonia. The mineral portion, or ash, left behind when all the combustible matter is burned away consists chiefly of phosphoric acid combined with lime and magnesia, as a compound called bone-earth, with smaller quantities of carbonate of lime, and, in still smaller quantities, the alkalies potash and soda ; also a little fluorine.

The value of bones as a manure chiefly depends on the animal matter and the phosphoric acid they contain. The former substance, in common with all such substances excep fat, yields, by decay in the soil, ammonia, and finally nitric acid ; while the phosphoric acid combined with lime and magnesia, under the same treatment, is slowly disintegrated, and conveyed by means of their roots, as we have previously observed, into the organism of plants, there to perform the important functions allotted to it.

The bones supplied for agricultural purposes consist of those of oxen, sheep, horses, etc., crushed to fragments, according to the size of which they are called half-inch or quarter-inch bones ; and some of still smaller size bone-meal. These bones have generally been deprived of their fat, and often of a portion of their gelatine ; and further, they always contain impurities in the shape of sand and earthy matters, and often materials of vegetable origin. For these reasons, commercial bone-dust is a mixture of very uncertain composition, and consequently its agricultural value differs to a corresponding degree. The following analyses will convey a good idea of the composition of bone-dust of two or three qualities :—

BONE MEAL, ETC.

	1.	2.	3.
Moisture	7.12	8.67	9.63
* Nitrogenized organic matter	29.34	27.19	84.17
Phosphate of lime	51.30	51.64	3.04
Carbonate of lime, etc.	11.88	9.82	2.20
Insoluble silicious matters	.36	2.68	.96
	100.00	100.00	100.00
* Containing nitrogen	3.84	3.64	11.25
equal to ammonia	4 66	4.42	13.66

We may say, in reference to these samples, that No. 1 is a specimen of quarter-inch bones of good quality ; No. 2, bone meal, of fair quality, but has a rather high percentage of sand ; while No. 3 is a very fine example of meat meal or flesh guano.

Some foreign bones contain flesh and gristle amongst them, and yield from 5 to 6 per cent. of ammonia and 38 to 40 per cent. of phosphates.

East Indian bones are now largely imported, and are similar in composition to ordinary bone meal, but drier, and sometimes with more sandy matter.

The nitrogen of raw bones is much slower in action upon the soil than that of manures having their ammonia as salts, or nitrate, or other animal matter.

Boiled or steamed bones contain about 58 to 60 per cent. of phosphate of lime, and about 2 per cent. ammonia.

There are also degelatinized bones with still less nitrogen, also bone flour ; the three latter are much more brittle than ordinary fresh bone, and this admits of their being more easily ground to fine powder.

Bones are sometimes adulterated with gypsum, more especially boiled bones, which it much resembles in appearance.

With the exception, perhaps, of occasionally dressing pasture land with bone meal, we should not consider it the wisest policy as a rule to use them in a raw state, because their decomposition by the action of the soil and atmosphere is then so slow that a considerable length of time must elapse before their full benefit is obtained : a property which may, in some cases, of course, be an advantage, and form an inducement to use them.

Apart from the intrinsic value of various qualities of bone-dust, as depending on the amount of phosphoric acid and nitrogen they contain, much of their practical value depends on the treatment they have received at the hands of the dealers and collectors.

In this country, where economy of material is in some trades (not including farming) carried to a degree of refinement undreamt of by uninitiated persons, bones in their raw state are too valuable to be at once delivered over to the farmer. They contain constituents that can be more profitably disposed of. As the agricultural value of bone-dust thus depends on the previous treatment it has undergone, it will be well to enumerate the more common modes of treatment pursued towards commercial bones. 1. By boiling the bones in open coppers the fat is extracted; this is removed by skimming, and sold for soap-making, etc. The bones, thus deprived of fat, are either at once supplied to farmers or are dealt with as in processes Nos. 2 and 3. Most of the bones supplied for agricultural purposes have been thus deprived of fat, and in this condition are superior to natural bones, because the fat that these always contain greatly retards their action in the soil. It is found that a piece of fresh bone buried under the surface of the soil undergoes little change, and for a length of time refuses to decay. This is explained by the fact that the fatty matter it contains diffused through its substance effectually excludes the air and moisture necessary to the decay of the animal portion of the bone: for this reason fresh bones are, for a length of time at least, next to useless in the soil, unless finely ground. 2. The bones, deprived of fat, are kept in a moist state in heaps for two or three months. Under these circumstances they heat or ferment, from the partial decomposition of the nitrogenous matter present. Much ammonia is produced, the greater portion of which is retained by the fat still remaining in the bones; a small quantity of this substance always being left, even after prolonged boiling. By this process the bones become softer, can be more easily reduced to powder, and are altogether better suited for use as manure. 3. Another system, followed in some districts where inferior sorts of cloth are manufactured, consists of extracting the gelatine after the fat has been removed. This is accomplished by boiling under pressure in closed vessels, when the gelatine is extracted, and by evaporation is converted into size. This impure size is used for giving stiffness or "body" to the commoner sorts of woollen cloths. Bones that have undergone this process are of course less valuable for agricultural purposes, since, the greater part of the gelatine being removed, there will be but little ammonia produced upon their decay in the soil; but, as the phosphate of lime is still present, bones of this kind will do equally well for the farmer, provided he can obtain them at a proportionate price, while their action is less tardy.

The value of bones as a manure is greatly dependent on the large quantity of phosphoric acid, in the shape of phosphate of lime, they contain. It will be remembered that this substance is in most soils present only in small quantities; and as it is required in the development of all cultivated crops, its artificial addition becomes necessary. This is most effectively done by the application of phosphatic manures. A further effect of bones is exerted by the animal matter they contain. This, upon decay, yields its nitrogen in an available form, which greatly assists the action of the phosphate of lime.

Bones are preferred to other more active phosphatic manures in cases where a gentle but continuous supply of phosphoric acid and ammonia is desirable. The effects of bones extend over several years, and are regulated by the state of division, or the size of the fragments of bones supplied. From the slow action of bones, they are well adapted for application to permanent pastures. We may now explain the matter adverted to in a preceding page, viz., the restoration of the fertility of meadow land by their use when ordinary farmyard manure is of no avail. In the case referred to, it is stated that permanent meadows had become partially exhausted from the continued grazing of cows, whose milk was disposed of in the production of cheese.

It is known that milk contains valuable nitrogenous and mineral constituents, which can only be supplied by the soil producing the fodder that the cows are fed upon; and as a large part of these substances received by the cow will be disposed of in the secretion of its milk, a proportionate quantity only of that contained in the food will be returned in the excrements. Hence, even if all the manure produced be returned to the land, the soil will still be robbed year after year of the whole of these compounds contained in the milk carried off the farm ; and however fertile or prolific in phosphoric acid a soil may naturally be, it must sooner or later feel the effects of this system, and show symptoms of exhaustion. As bones are rich in plant-food, we can easily account for the renewed vigour of the soil consequent on their addition.

We thus perceive the necessity of adding adequate quantities of suitable manure to pasture land employed for the production of dairy produce. In all cases phosphoric acid in some form must be supplied, in addition to ordinary manure, to compensate for the quantities of this material carried away in the shape of milk, cheese, meat, etc.

Dissolved Bone Manures.

The use of this material may be regarded as an improved method of applying bone manure to the land. We have stated that the activity of bones in the soil is in direct proportion to the number of fragments into which they are broken up. We can easily understand that this should be the case, for the finer the state of division the greater must be the surface exposed to the action of the roots of plants ; hence they are able to obtain and make use of larger supplies of nourishment in a given time. By dissolving bones, etc., we produce this effect in a high degree ; for, on applying them to the land, they are separated into a multitude of particles infinitely smaller than can be prepared by any amount of grinding or other mechanical means. It is to this circumstance that the superior effect of superphosphate, as compared with bone-dust, in the soil is mainly due.

An idea of the minute state of division into which the bone material is separated when dissolved and added to the soil may be formed from the following simple yet interesting experiment. A small piece of bone is placed in a wineglass, or any convenient receptacle, and covered with diluted hydrochloric acid (the spirits of salts of the shops, before noticed), and left for two or three days; by this time the bone will have become quite soft, owing to the extraction of its earthy or mineral portion, which is dissolved in the clear acid liquid. If we now add to some of this clear liquid a little hartshorn or ammonia, or even common soda, a white, bulky, flocculent substance will separate. This is the earthy portion of the bone in a finely divided state: it may be regarded as bone material broken up by chemical means. The same substance may be obtained by adding a small quantity of any manure containing dissolved phosphate to water, allowing it to stand till clear, and testing this watery solution with ammonia, or soda, as in the former experiment.

When bones moistened with water are mixed with sulphuric acid or oil of vitriol, much heat and steam, with unpleasant-smelling gases, are given off, while the bones are more or less attacked and dissolved. On standing, this mixture dries up and becomes solid, and, if the process has been properly conducted, forms a friable, loose, moist grey powder in which part of the bone appears but little changed. This powder is dissolved bones. The essential difference between this substance and the original bones is that the dissolved bones are for a great part soluble in water. The beauty of this process, however, lies in the fact that not only bones, but other combinations of phosphate of lime, otherwise useless, as the stones and rocky minerals before mentioned, can by this means be converted into superphosphates. For this reason, minerals of the kind are eagerly sought for, and constantly being discovered. Thus we perceive, by the magic of chemistry, useless stones are changed into fertilizing manures, and these again, by still greater magic, actually become part of our daily food.

The chemical changes involved in the production of superphosphate, from bones, or either of the above-mentioned raw materials, may be thus explained : in all these materials the phosphoric acid is combined with lime in the form of tricalcic phosphate, or bone-earth, as it is called. Now, it must be stated that in all chemical decompositions the right of might prevails ; the stronger substance, if so disposed, always driving out the weaker one. Thus, when we add sulphuric acid, or oil of vitriol (which is the strongest of all acids at ordinary temperatures), to the combination of phosphoric acid and lime, called bone-earth, the weaker phosphoric acid is displaced, and the sulphuric acid takes its place, to form sulphate of lime, or plaster-of-Paris. But in practice all the lime is not taken from the phosphoric acid by oil of vitriol ; a part still remains, and forms, with the phosphoric acid, a new combination, called monocalcic phosphate or soluble phosphate of lime. This change will perhaps be better understood by a glance at the following plan of the operation :—

	Materials employed.	Products.
Insoluble phosphate of lime, as it occurs in bones and minerals, consists of three quantities of lime and one quantity of phosphoric acid (anhydride) ; we may therefore represent it as... ...	Phosphoric acid...	Soluble or monophosphate of lime.
	Lime	
	Lime	Sulphate of lime, gypsum, or plaster-of-Paris.
	Lime	
On adding sulphuric acid or oil of vitriol, two of these quantities of lime are removed ...	Sulphuric acid ...	
	Sulphuric acid ...	

From this we perceive that in these dissolved manures there is a soluble combination of phosphoric acid, on which its value chiefly depends, and a larger quantity of sulphate of lime obtained as a secondary product. This latter substance is comparatively of little value as a manure.

When phosphate of lime of mineral origin, as from any of the minerals above mentioned, is used in this manufacture, the value of the resulting product is almost solely dependent on the amount of soluble phosphate of lime it contains. The same will be the case when the superphosphate has been prepared from the substance technically known as "bone-black", or the refuse animal charcoal of sugar-refiners ; also that made of bone-ash. In all these cases the superphosphate produced is purely a phosphatic manure ; that is to say, its effects in the soil are entirely due to the phosphoric acid, and in a much minor degree to the gypsum present in it. But when bones are used in the manufacture the resulting manure is rendered more valuable by the animal matter they contain. A part of this is transformed into ammonia, which, meeting with sulphuric acid, becomes sulphate of ammonia ; while of the remainder a considerable portion is converted into a form also soluble in water.

When manufacturing this substance on a large scale all the insoluble phosphate of lime is not rendered soluble—a part of it always remains after the process, in its original state. The amount of this unchanged material left in the product depends on the quantity of sulphuric acid or oil of vitriol used in the process, and on the quality of the bones or other kind of phoshate employed ; also upon the degree of fineness to which they are ground before dissolving. For these and other reasons this material is a mixture of most uncertain quality, scarcely two samples ever being found exactly alike.

It is a fully recognised fact that a well-made bone-manure is one of the best forms in which money can be expended with a fair prospect of a remunerative return. It is often a question of much interest to buyers of dissolved bones as to whether it is better to use those made from bone and acid only, and coming strictly within the designation of pure dissolved bones, or those now termed dissolved bone compounds, in which mineral phosphates, bone-ash, and animal matter, other than bone, are also used in their manufacture. The former are necessarily higher in price from the comparatively limited supplies of bone, but it may be fairly questioned whether they are more effective in the field, for the reason that it is difficult to get a high percentage of soluble phosphate from bones alone; hence it is not only more economical, but at least as effective, to obtain the soluble phosphate from mineral sources, and to use only so much bone as is necessary to supply the insoluble phosphate, which does best service in coming in during the later stages of the growth of the crop. Again, as to the animal matter supplying the nitrogen, there is no valid objection to its being supplied in part in other forms than bone, provided it is available as plant-food. In bone itself the nitrogen is by no means readily available unless well decomposed by acid, and may otherwise remain inert for a length of time in certain soils. On the other hand, if buyers prefer their manures made from bone alone, or the nitrogen derived only from this source, and are prepared to pay accordingly—although in most cases we should consider it a needless outlay—of course these terms must be complied with, and whether this is so or not is a question frequently put to us when a sample is sent for analysis.

Bone manures of course contain nitrogen derived from the organic matter of the bone, hence the amount of ammonia in them is an item of importance, and should always be shown in an analysis.

The advantage gained by such manures is supposed to consist chiefly in their having a more lasting character, since by the slow disintegration of the bones in the soil, the phosphate of lime and nitrogen they contain are more gradually supplied to the roots of plants throughout a longer period than in the case of mineral superphosphates before considered. This is undoubtedly a valuable property of bones as manure in the case of soils of a sandy character, in which it is a decided advantage. In the majority of soils, however, where there is a fair proportion of clay to absorb and retain the soluble phosphate until taken up by the plants, its utility may be questioned. We must also bear in mind that soluble phosphate, when applied to the greater number of soils, speedily assumes a form which water is not able to dissolve ; indeed, it is said that soil will precipitate the phosphoric acid from a solution of superphosphate within twenty-four hours, hence we see that under ordinary circumstances no great loss of this material by drainage need be anticipated. Owing to these invaluable properties of soils the plant-food present is safely stored until required by the plant, so that, supposing a superphosphate to have been properly distributed through the soil, the roots of plants would find fresh supplies of available phosphates, so long as they continued extending and multiplying, during the whole period of the growth of the crop.

The effects of bones as more lasting constituents of manure are brought about by the insoluble phosphates, or that portion left in an undecomposed state, since that which has been rendered soluble acts in the same manner as the soluble phosphates from mineral sources. We have seen that the insoluble phosphates of the latter class are commonly believed to be of little or no importance—we should say, perhaps, so far as the buyer of such manures is concerned, since to the manufacturer they are of importance, inasmuch as the value being in such cases determined by the percentage of soluble phosphate, all that is left insoluble is a loss to him. In bone manures, on the contrary, the insoluble phosphate forms an item of value, that is, when, as should be the case, it is derived from bone-dust.

Bone-dust which has thus gone through the mixing process, and which, although not chemically dissolved, has yet been rendered brittle and friable, as we find it in the best bone manure, is superior to bone-dust in its usual condition, as it admits not only of readier assimilation by the plant, but allows of a more equal distribution in the soil, upon which so much of the practical value of a manure depends.

This leads us to remark that in the majority of manures of this class the bone-dust used in their manufacture is too coarsely ground, and we have no hesitation in saying that the efficacy of such manures would be much enhanced by the substitution, in part at least, of a finer-ground description of bone-dust. An impression is common amongst many manufacturers that farmers prefer to see the pieces of bone in manure, and this is no doubt one cause of the defect above referred to ; but as we frequently find pieces of bone in such manures of an inch or inch and a half in length, which may remain undecomposed for years, there is yet room for improvement in this particular, while still allowing for the scrutiny of those of their customers who prefer the evidence of their eyes in buying manures.

The presence of visible fragments of bone is, however, no evidence of the excellence of a manure, since such fragments may, and often do, consist entirely of bone-ash, which in a coarsely-broken state has the same reticulated structure, and cannot often be distinguished by an unpractised eye from fresh or unburned bone. Or the bones may have been added to a mineral superphosphate, and so escaped the action of the acid and mixing. This should not be so, for naturally they are not equally useful in the soil.

Bone-ash, when used, should be made all soluble, as far as practicable, of which it admits with greater ease than most materials of the kind, and on this account has long been considered one of the best sources of soluble phosphates ; but in an undissolved state, although perhaps superior to mineral phosphates in the same condition, it is yet very inferior to bone-dust, and is by no means a substitute for it. In buying bone manures, therefore, we should bargain for insoluble phosphates in *form of bone*, since that from bone-ash is frequently styled "bone phosphate". The following passage concerning manures of this character is here appropriate, and is quoted from my report on thirteen samples of manure sent to me for analysis by the Barnstaple Farmers' Club, and published in the *North Devon Journal*:—

"In some of these manures, it will be observed, a high proportion of insoluble phosphate occurs, which consists of undissolved bone and bone-ash—the value of the latter, as food for plants, especially when in the form of coarsely-broken fragments, being at best doubtful, at least so far as all present effect is concerned; its addition, moreover, to the soil in this state entails a practical waste of phosphate of lime, which should be avoided by a better mode of manufacture."

But little, if at all, inferior to manures whose soluble is derived from bones, bone-ash, etc., are bone-manures containing a similar quantity of soluble phosphate obtained from mineral sources, with sufficient fine bone-dust to furnish the insoluble phosphate and ammonia.

RECENT EXAMPLES OF DISSOLVED BONE-MANURES.

	1.	2.	3.	4.
Moisture	14.28	12.16	12.26	10.40
*Organic matter, etc.	21.30	20.24	25.60	28.13
Monophosphate of lime	13.11	17.56	13.65	11.05
equal to bone phosphate made soluble	(20.46)	(27.40)	(21.30)	(17.24)
Insoluble phosphates	7.16	8.67	18.13	21.03
Sulphate of lime, etc.	38.98	37.74	29.43	27.43
Insoluble silicious matters	5.17	3.63	.93	1.96
	100.00	100.00	100.00	100.00
*Containing nitrogen	1.30	2.10	1.70	2.70
equal to ammonia	1.58	2.55	2.06	3.55

In commenting upon these analyses, we may say that No. 1 is a good ordinary dissolved bone compound, and No. 2 a special dissolved bone compound. The signification of the word "compound" attached to these samples has been mentioned. No. 3 is a pure dissolved raw and boiled bone, while in No. 4 we have an example of a pure dissolved bone. In the two latter cases a considerable amount of reverted phosphate was present, which is often the case in this class of manures. An explanation of the reason why will be found on page 295.

The gypsum and alkaline salts (shown together) in these manures are possessed of a certain value, but a much lower one than that of bone material. The water and small quantity of sand and earthy matters are unavoidable impurities, and, unless excessive, need not be taken into account in estimating the value of the manure.

It should always be remembered by farmers, in purchasing all kinds of artificial mixtures, that the dearness or cheapness of a manure is not determined by its price, but by the amount of fertilizing materials it contains, and the degrees of fitness of these materials for action in the soil.

In the case of manufactured manures, much of their agricultural value depends on the mechanical condition in which they are supplied—the extent to which their constituents have been pulverized and intermixed. The richest manure, chemically speaking, will be of little use unless it is moderately dry, reduced to fine powder, and its constituents thoroughly incorporated. This must be borne in mind in judging of the value of a manure, and a proportionate price must be allowed for the degree of completeness with which these matters have been attended to. Athough in theory dissolving bones, etc., is a very simple matter, in practice it is found somewhat troublesome, from the difficulty of producing a manageable article ; and a great deal of experience and skill are required to prepare a manure of the requisite chemical strength and mechanical condition at a remunerative price. For this reason we would recommend farmers never to attempt to dissolve their own materials, since, in most cases, their efforts will result in the production of a compound either too wet or too dry, or otherwise unmanageable, and altogether remote from the character of a good sample. The best plan of obtaining this material is to purchase it of some well-established manufacturer of known respectability, who will readily guarantee its quality. For the reasons above stated, the exact value of a manure cannot be told by judging solely of its composition as revealed by an analysis; on the other hand, we can never arrive at the real value of a manure without an analysis. The perfection of mechanical texture will be useless unless its chemical constitution corresponds. The importance to be attached to mechanical condition must always be added to that depending on the amount of fertilizing materials it contains: thus we can only arrive at the precise value of a manure by comparing its composition, as shown by analysis, with its external properties.

The material now known as vitriolized bones often has but a small amount of actually soluble phosphate with a large proportion of insoluble bone phosphate, and some reverted phosphate. They are found of service when a slightly more rapid effect is desired than can be obtained from raw bones.

MINERAL SUPERPHOSPHATES.

The universal efficacy of superphosphate, and the manures supplied under other names in which it is the basis, is sufficiently well known and explained by the facts we have just briefly noticed. Its value for the root-crop especially, upon which in the present system of agriculture so much depends, can scarcely be overrated, and the means it affords of increasing our stores of available nitrogen, by the green crops, as previously pointed out, furnishes a resource which is yet hardly sufficiently appreciated by the majority of practical men.

As before intimated, the advancement made of late years in the production of superphosphate and other phosphatic manures consists more essentially in an extension of the application of mineral phosphates to their manufacture. The principal advantages so gained may be thus enumerated :—

1. The production of manures with a much higher proportion of soluble or available phosphate of lime than could be made from bone-dust.

2. The preparation of much drier, more uniform and pulverulent manures—or a superior "mechanical condition" which adds materially, as we shall presently perceive, to their practical value.

3. The more economical and advantageous employment of bone-dust by using it in conjunction with these mineral phosphates ; the latter for giving the soluble phosphates, while the bones furnish a valuable insoluble phosphate and also some nitrogen. Many of the best bone-manures now in use are of this description, as we have seen in the foregoing pages.

4. A considerable reduction in the cost of manures so prepared.

5. The production of manures, or their conversion to a manageable condition in less time than when bones are used.

These mineral phosphates, to give satisfactory results, must be exceedingly finely ground (a powder almost as impalpable as flour being requisite). They are then acted upon by sulphuric acid in the same way as bones, great care being necessary to thoroughly mix the ingredients, that the mineral may be brought as completely into contact with the acid as possible, and a thorough decomposition effected : for upon this the success of the process depends. The chemical changes which take place are the same as those described on page 283, carbonic acid gas and other volatile products being driven off.

So soon as the mixture has dried up, which it does very quickly under skilful management (often in twenty four hours), we obtain a manure having a composition similar to the examples given below, which represent superphosphate thus prepared without bone-dust. Those containing this material and other sources of organic nitrogen are now known as dissolved bones, dissolved bone compounds, etc., the term superphosphate being used to distinguish these dissolved minerals.

RECENT EXAMPLES OF SUPERPHOSPHATES.

	1.	2.	3.	4.	5.
Moisture	14.80	16.24	14.36	—	—
Water of combination, etc. ...	9.13	8.70	10.17	—	—
Monophosphate of lime ...	18.97	17.10	11.15	—	—
equal to tribasic phosphate of lime made soluble	(29.60)	(26.68)	(17.40)	34.80	38.46
Insoluble phosphates	4.12	2.16	19.22	3.14	—
Sulphate of lime, etc.	46.96	50.04	35.47	—	—
Insoluble silicious matters ...	6.02	5.76	9.63	—	—
	100.00	100.00	100.00		

With regard to these analyses we may remark that No. 1 is rather high for ordinary superphosphates, although such are frequently obtained under good management; 26 to 27 per cent. of soluble phosphate is, however, about the average. No. 2 is an example of this kind; while No. 3 is low, the mineral phosphate not having been sufficiently decomposed—a fact disclosed by the large proportion of insoluble phosphates present. Nos. 4 and 5 are examples of analyses in which the soluble, or soluble and insoluble only are given. These partial analyses are often required, and prove very useful: the two latter results serve to illustrate a class of superphosphates containing a high percentage of soluble, and are valuable for special purposes. For ordinary use, however, the former examples would appear more suitable.

The form of stating results of analyses here given is that now generally adopted; that used for dissolved bones has been given on page 289.

A few words in explanation of the term soluble phosphate may be useful: this does not mean the amount of soluble combinations of phosphoric acid present, but the quantity of tricalcic phosphate to which these are equal, as shown above in brackets.

Again, with regard to the "water of combination", a word of explanation may be requisite. Water of combination signifies the water chemically taken up by the sulphate of lime in "setting", or solidifying, which is then said to be "hydrated", and is different from that present merely as moisture, which can be driven off in drying, while the former cannot. Sulphate of lime in this condition is also called "gypsum", and is better known as "plaster-of-Paris", which becomes gypsum after it has been used to prepare plaster-casts, etc.

It is to this property of sulphate of lime, insignificant as it may at first appear, or its power of taking up chemically about a fourth of its weight of water, besides what it absorbs as moisture, that superphosphate and similar phosphatic manures owe one of their most valuable properties, viz., that of drying up or solidifying spontaneously (as we have mentioned, in so short a time as twenty-four hours, from a fluid mass), and without which they would never have become so valuable in agriculture.

It should also perhaps be mentioned that although sulphate of lime is usually classed amongst the unimportant constituents of superphosphate, it possesses a certain value as manure, especially for clover and allied plants, and on some soils in which it is deficient exercises a marked improvement—the quantity added to the soil when superphosphate is applied has been given on an earlier page. An impression is also very common that the gypsum occurring in large quantities in all superphosphates is added ; although this is occasionally true as regards certain bone-manures which it is used to dry up, it is formed in all ordinary cases from the decomposition of the phosphate of lime by the sulphuric acid used. The small quantity of alkaline salts and "insoluble" or sandy matters are also derived from the phosphatic materials employed. A small proportion of nitrogen, equal to about .25 to .33 per cent. of ammonia, is also often found in mineral superphosphate ; being derived from the acid, and although the amount is small, it may often serve a useful purpose.

A point of considerable importance to buyers and sellers of dissolved bones, superphosphate, etc., is the reverted or reduced phosphate, concerning the formation of which we abstract a passage from an article recently contributed by one of us to the *Mark Lane Express;* other extracts from this source appear under nitrogenous manures, etc.: "The presence of iron and alumina in a superphosphate has the effect of causing a part of the soluble phosphate to assume a different composition, or, technically speaking, to 'go back' or become reduced and no longer soluble in water. A similar effect is produced by animal matter, as we see by referring to the comments upon the analyses of dissolved bones, page 289. It will at once be seen that a large quantity of the two former substances, which, unlike animal matter, have no manurial value of their own—at any rate, under these circumstances we may assume they have none—will greatly detract from the value of a sample; for although this reverted or reduced phosphate is more valuable than the insoluble form, it cannot, we think, be considered to possess a value anything like soluble phosphate. A safe position to give it is probably one between the latter and the phosphate present in bones.

"Some, in objection to this line of argument, may say that soluble phosphate itself, after incorporation with the soil, and therefore as it reaches the roots of plants, has also become incapable of dissolving in water; but a moment's reflection will show us how far more thorough must be the distribution of a soluble salt within the soil than one of an opposite character; hence this reason alone entitles soluble phosphate to hold a very much higher position." Another cause of the formation of this reverted phosphate is said to be the action of undecomposed phosphate of lime.

In thus preparing superphosphate from the mineral phosphates it is the object of the manufacturer to reduce the greatest possible quantity of the phosphate of lime present to the soluble condition, since that which is left undecomposed has but little value as manure, and is generally left out of consideration in judging of the value of such samples. It is also his object, in these days of cheap acid and comparatively low prices for superphosphate, to add as much of the former as possible, for it is chiefly through this means he obtains his profit. All technical details of the process would obviously be out of place in a book of this character, but we shall be happy to supply such information on application.

With regard to the alleged impurities communicated to the soil by mineral phosphates, there is no reason, in our opinion, to apprehend the slightest mischief from this source. It is true that arsenic (arsenious oxide) is sometimes found in the sulphuric acid used in preparing these manures (of which those prepared from bone would evidently be equally guilty), and by which it might become disseminated through the soil of our fields, as brought to notice some time since by a chemical authority. From experiments, however, made by one of us at the time, which were published in the *Gardeners' Chronicle*, and our observations since, we are of opinion that the acid used only rarely contains an appreciable amount of arsenic. Moreover, it is then at least doubtful if plants have any power of absorbing the arsenic so communicated. Our own impression is that they do not.

Again, the ammoniacal salts prepared from gas-works, when imperfectly purified, have at times a pernicious effect on vegetation—entire crops having been known to be destroyed by such means ; but injury of this kind is of rare occurrence, and may be always avoided by a little caution in their selection.

Another point at one time under question was, whether the bones and offal of animals tainted by cattle-plague or other disease could be safely used for manure. We consider that with due care in the mixing operation, so as to insure the bones getting the full effect of the acid employed, they might be thus used with the greatest safety. Indeed, the chemical decomposition of the entire carcass, by means of boiling sulphuric acid, offers, we think, one of the best means of disposing of them, as every species of organization, either in the shape of the germs of disease or otherwise, would effectively be broken up by this process.

Raw Mineral Phosphates.

Doubtless a brief consideration of the composition and properties of some of our mineral sources of phosphoric acid so largely used in the manufacture of superphosphate will prove of interest. We will therefore proceed to this subject at once, as we have reached a favourable position for doing so. We shall first give the tables of analyses, and afterwards comment upon them.

RECENT EXAMPLES OF SOUTH CAROLINA RIVER ROCK.

Analysis sample dried at 212° Fahrenheit :—	1.	2.	3.
Moisture	—	—	—
*Phosphoric acid	26.80	26.10	25.40
Lime	43.37	43.32	42.72
Other constituents not determined ...	18.43	19 48	17.55
Insoluble silicious matters	11.40	11.10	14.33
	100.00	100.00	100.00
*Equal to tribasic phosphate of lime...	58.51	56.98	55 45
Moisture sample :—			
Moisture	1.80	1.90	1.60
Tribasic phosphate of lime calculated for latter state	57.45	55.89	54.57

This method of stating an analysis of these materials is that now most generally used. The preceding results may be taken as fair examples of phosphates of this class. From these the greater part our superphosphate is made, and, indeed, for ordinary qualities nothing better could be wished, because they contain but small amounts of undesirable constituents. They are also very regular in yielding satisfactory results when dissolved ; again, they have the great advantage of being forthcoming in constant and abundant supplies. There are several varieties of these phosphates, but in general merit they much resemble one another. Other examples of a somewhat similar character are the South Carolina land rock, Horseshoe, Chisholm, Peace River, and some other phosphates.

EXAMPLES OF FLORIDA PHOSPHATE IN DRY STATE.

	1.	2.	3.	4.
Moisture	—	—	—	—
*Phosphoric acid	37.30	36 80	36.02	34.06
Lime	50.36	50.74	50.54	49.19
Oxide of iron	.50	.52	.61	.73
Alumina	1.22	1.38	2.04	3.10
Other constituents not determined ...	7.24	7.63	6 65	8.90
Insoluble matters	3.38	2.93	4 14	4.02
	100.00	100.00	100.00	100.00
*Equal to tribasic phosphate of lime ...	81.43	80.33	78.63	74.35

Nos. 1, 2, and 3 are examples of the variety known as Dunnellon phosphate, which we see to be of very high quality. We shall have observed that the above results are given in the dried sample, but a separate moisture sample is as a rule also sent, and the certificate of analysis made out in the way shown for South Carolina phosphate. This new Florida phosphate has been but lately introduced, and appears to be of more than usual interest, as, apart from its affording about 78 to 80 per cent. of phosphate of lime, it promises to be forthcoming in large quantity. Many of the new phosphates which appear from time to time are of little practical importance, from the limited supply and uncertain quality. We have analysed many samples of this phosphate since its introduction, and from the results obtained it appears to contain, besides the phosphate as above, about 3 per cent. carbonate of lime, .5 to .8 of oxide of iron and about 2 per cent. of alumina, about 4 per cent. of silicious matter and a little fluorine. The iron and alumina are of course a drawback, but, so far as we have heard up to the present, do not give rise to reverted phosphate to the extent that might be expected ; in fact, it would appear in some cases, at least, that the soluble phosphate made from it increases after keeping. The hint here given concerning iron and alumina, together with the remarks made under reverted phosphate, reveal to us the reason why an excess of these constituents is undesirable ; for when much is present we shall readily understand that very unsatisfactory results may follow : latterly more attention has been given to these compounds. Thirty-seven to forty per cent. of soluble phosphate has been obtained from this phosphate. The iron and alumina vary somewhat in different samples, and should be shown in the analysis—which, by the way, requires special treatment and particular care. This material resembles the higher kinds of Bordeaux phosphate, largely used some years since, and which also contained iron and alumina, the latter often predominating. In the comparative scarcity of high-class phosphates, we think this one is likely to prove a valuable acquisition, either for making high-grade superphosphate, or in conjunction with lower classes of phosphates to bring them up to a workable standard.

EXAMPLES OF VARIOUS RAW PHOSPHATES.

	1.	2.	3.	4.	5.
Moisture	.36	.40	—	—	1.64
Phosphoric acid	40.20	19.20	31.90	27.50	26.68
Lime	53.17	53.14	37.80	38.14	43.76
Other constituents not determined	6.27	24.30	27.84	13.73	20.79
Insoluble silicious matters ...	traces	2.96	2.46	20.63	7.13
	100.00	100.00	100.00	100.00	100.00
*Equal to tribasic phosphate of lime	87.76	41.91	69.64	60.03	58.25

No. 1 is a fair specimen of Curaçao phosphate. We see at a glance what exceptionally valuable material it is ; indeed, there is little else than phosphate of lime present, and the undesirable compounds may be neglected. Were larger quantities forthcoming they would doubtless be speedily purchased.

No. 2 represents an average Belgian phosphate. It contains a good deal of calcium carbonate, but dissolves very readily, and has under 1 per cent. of oxide of iron and alumina.

No. 3 is a Navassa phosphate. This contains a good deal of oxide of iron and alumina, and is sometimes called Navassa guano ; it is less mineralized than some other sorts of phosphates.

No. 4 furnishes us with an instance of a low Florida phosphate. It contains about 3.5 per cent of oxide of iron and alumina.

No. 5 exhibits the composition of Cambridge coprolites. These are not so much used as formerly, although they supply a most excellent material from which to make superphosphate, and are of home production.

RECENT EXAMPLES OF PARTIAL ANALYSES OF RAW PHOSPHATES.

	1.	2.	3.	4.	5.	6.
Phosphoric acid ...	36.65	33.20	24.60	33.12	28.90	26.50
Equal to tribasic phosphate of lime ...	80.01	72.48	53.70	72.30	63.09	57.85
Oxide of iron and alumina	—	1.98	4.76	2.20	3.40	3.86

Analyses of this partial character are often given when a more complete one is not required.

Nos. 1, 2, and 3 supply instances of Somme phosphate, which has latterly been considerably used, although the purchaser must exercise caution when buying, as it varies greatly in practical value. No. 1 is an exceptionally high sample, lately analysed by us, the result being very closely confirmed by an eminent French chemist.

Nos. 4 and 5 are Canadian phosphates, which we see also vary rather widely. This kind of phosphate, when very finely ground, is valuable for dissolving; but, if not thus ground, disappointing results will follow.

No. 6 is an example of what is known as Osso phosphate. Bone-ash is of course a most valuable material for making superphosphate, but is less used than formerly. It occurs in all qualities which are dependent upon the proportion of dirt present, and also on the percentage of moisture. The phosphate of lime may vary from about 60 to 80 per cent., and over.

We have already said that we do not think it desirable to supply any directions for dissolving these various phosphates, as the subject has been fully dealt with by one of us elsewhere. Shortly, however, it may be stated that Chamber acid, having a specific gravity of about 1.60, is generally employed, and a good practical rule is to use as much acid as the phosphate will take, so long as we do not interfere with the drying of the product.

The application of very finely-divided raw phosphates has in recent years been shown to be of greater service than was at one time supposed. Exceedingly fine grinding and the presence of moisture are essential to success. It is also desirable to have certain conditions of soil and crops for this purpose. We, therefore, hardly think it likely to be largely adopted for general purposes, for which superphosphate is certainly more suitable.

Other phosphates in use besides those already mentioned are Sombrero, Aruba, Spanish, etc.

Peruvian Guano.

Guano is a natural product, consisting of the excrement of sea-fowl, more or less altered by fermentation and drying. In certain districts of the tropics, where little rain falls, the coasts and islands frequented by large numbers of sea-birds become covered with accumulations of their dung, which, after the occurrence of the changes referred to above, constitutes the substance we call guano. Beds of this material have been discovered in several localities, the more extensive being upon islands off the coast of Peru. From this place the greater part of the guano met with in commerce is obtained ; and as the climate of the locality is particularly favourable for the preservation of this substance, the guano of that district is not only the most abundant, but of better quality than that found in most other places. These original deposits have long since been exhausted, and we have now to be satisfied with a much lower quality of Peruvian guano.

Damaged guano is sometimes purchased at a low price by unscrupulous dealers, who afterwards dispose of it to unsuspecting persons under the name of genuine guano—

which indeed it is, but not of the best quality. For this reason, in purchasing guano, care must be taken to see that the article supplied is really what it is represented to be. But this is not the only kind of imposition one is liable to in purchasing guano ; as we shall presently see, the substances offered for sale and purchased under the name of guano are often altogether different from the genuine article, even of damaged quality.

The external properties of Peruvian guano are tolerably well known. As generally met with, it is in a moderately dry light powder, interspersed with lumps of harder material. These lumps are often difficult to break, and when broken present a crystalline structure. The colour of guano is generally a light brownish red or fawn-colour. It is also possessed of a peculiar unpleasant smell, which is popularly supposed to be due to the escape of ammonia. But this is a delusion ; ammonia does not escape in any appreciable quantity from dry guano, even when it is exposed for a length of time to the heat of the sun.

That the smell of guano is not due to the escape of ammonia may be proved by a simple experiment. If we moisten a little of the substance with sulphuric or any other acid, and now dry the mixture, we find that the smell is still present. This could not be the case if it were caused by the volatilization of combinations of ammonia ; since, after the addition of acid, all the ammonia that could escape would have become fixed in the manner described in a former chapter.

The nitrogenous portion of guano contains many of the same compounds that are found in the urine of domestic animals, and noticed when speaking of farmyard manure ; so that we may regard this portion of guano as urine divested of its large quantity of water. Another most important constituent of guano is the phosphate of lime or bone material. The compounds included under the item "alkaline salts" consist of potash and soda combined with sulphuric, carbonic, and phosphoric acids. With this latter acid the potash and soda are especially valuable, since in this form they are readily soluble in water. A similar compound with ammonia is also occasionally present; oxalates are also found, and are supposed to have a beneficial effect in decomposing the phosphate of lime.

Unless the farmer is careful in buying this material, or if, in mistaken policy, he purchase a sample apparently but slightly damaged, at a reduced price, the substance he uses under the name of guano will possess qualities very different from and much inferior to those above described. Guano offers too great a temptation for adulteration to be resisted by unscrupulous manure-dealers: its high price, the facility with which foreign substances can be mixed with it, and the difficulty of recognizing such admixture by persons ignorant of chemistry, account for the fact that guano, of all other artificial manures, is most subject to adulteration.

In some cases this adulteration is but clumsily effected, and can readily be detected by persons acquainted with the appearance of genuine guano; but occasionally adulterated samples are met with so skilfully mixed, and the natural texture of guano so craftily imitated, that the most experienced judges are deceived by the appearance. In these not unfrequent cases chemical analysis is the only means at our disposal for detecting the adulteration. In all cases this is the only method of ascertaining the real value of guano.

The following simple experiments are often highly useful for enabling one to ascertain whether a sample of guano is adulterated or not:—1. A small quantity of the sample is mixed with quicklime and water to a paste in a tumbler, glass, or other convenient vessel. A strong smell of ammonia or hartshorn should be given off: the smell will be strong in proportion as the guano is good. 2. A little of the sample is burned on a piece of tin-plate over a lamp or a clear fire: the greater part of the guano burns away, leaving a white or slightly grey ash. If the ash is of a red or brown colour, we may infer that the specimen is not pure. Further, this ash will dissolve almost entirely in muriatic acid, if the guano is pure; whereas, in the case of an adulterated sample, a quantity of substance will remain undissolved in this liquid, even after standing for two or three hours.

RECENT ANALYSIS OF GUANO.

	1.	2.	3.
Phosphate of lime	30 10	42.13	16.75
Nitrogen	7.02	4.40	7.60
equal to ammonia	8.52	5.34	9.23

No. 1 supplies an illustration of a sample of what is at present considered good quality Peruvian guano.

No. 2 is an example of a different class of the same material; while in No. 3 we have an analysis of fish guano, concerning which we shall have more to say later on.

Peruvian guano is not so much used as formerly, although it must still be considered the best all-round manure, and of course continues to command a relatively high price, which cannot, however, be considered dear when we bear in mind its manurial value, which depends not only upon the quality and value of its constituents, but also on their perfect natural blending. All its phosphates are readily available to plants, although only a portion of them is actually soluble in water. Equalized Peruvian guano is now prepared, and sometimes preferred.

Most of the complaints occasionally raised against this manure, and the disappointments that sometimes follow its application, may be traced to injudicious methods of employing it, arising from ignorance of the fact that this is too stimulating a manure, too concentrated, to be used but with the utmost caution.

Phosphatic guanos are also less generally employed than at one time, although they form one of the best materials for the application of finely-ground undissolved phosphates; a result probably due, at least in part, to their unmineralised condition ; the most usual method of applying them, however, is as superphosphate.

This variety of guano is supposed to have originated from a similar source to Peruvian guano, with the exception of having been exposed to less favourable climatic conditions ; hence the ammonia and other nitrogenous compounds have almost, or entirely, disappeared.

Fish guano, which is used in considerable quantities, is prepared from fish-offal. If care is bestowed upon its production—a point apparently now better understood—a very useful material is formed, the phosphoric acid and nitrogen, constituents shown by the analysis to be present in considerable quantities, being yielded with moderate rapidity in the soil. Fish is often employed in the manufacture of dissolved bone compounds, and satisfactory results are frequently obtained.

This material, when of good quality, assumes a powdery and comparatively dry state. Much moisture, large pieces of bone, and an excessive number of teeth should be avoided, as they interfere with its value and condition.

Special Manures.

We now pass on to consider a class of manures prepared for special purposes. In these the nitrogen, or a part of it, often exists as nitrate of soda, or sulphate of ammonia. Such mixtures are doubtless valuable under some circumstances, only, for obvious reasons, they must not be applied to the land at a season when they are likely to be exposed to the wasting action of rain before the plants are able to assimilate the constituents most liable to loss from this cause. The nitrates present in such manures are easily overlooked in analysis unless especially sought for, as they are not determined by the ordinary methods used in the estimation of nitrogen. Potash salts are also added for some crops, and appear in results under alkaline salts. They are only separately stated when such a desire is expressed, as their determination involves a distinct and special operation.

The basis of these special manures is superphosphate, to which are added the substances named above, and in some a certain proportion of bone and animal matter. Under this group we have corn manure, potato manure, grass manure, etc., etc.

Many of the special "turnip manures" now supplied are mixtures of bone manure and superphosphate ; in some a proportion of fine bone-dust is separately added, more especially in those intended for use in districts where it is customary to use a mixture of bone-dust and superphosphate for these roots. We should be inclined to regard this practice in the majority of instances as merely a transition from the older one of using bones alone, rather than as a proceeding based on practical evidence of its value, and should recommend in such places the trial of a good superphosphate, either alone or with a much smaller quantity of fine bone-dust.

"Mangel manures" are mostly prepared from bone manures or superphosphates, with a considerable proportion of common salt, which seems to be especially favourable to the growth of this useful crop. When, as is usually the case, a heavy dressing of farmyard dung is also supplied, any further addition of nitrogen in the artificial manure is unnecessary, otherwise ammonia must be added. As there seems to be scarcely any limit to the weight of mangels that may be grown by skilful management, the liberal use of artificial manure for this crop will generally be well repaid in the produce.

A good mangold manure may be made by adding 3 cwt. of common agricultural salt to a ton of good superphosphate, and using 5 to 7 cwt. of this mixture to the acre when dung is used.

In many cases these mixtures are prepared on scientific principles, and their ingredients arranged in the proportion found by numerous well-conducted practical experiments to be best adapted for promoting the growth of the particular crop they are intended to benefit. Hence, if mixtures of this kind can be procured of respectable manufacturers, it may often be advantageous to employ them in preference to any of the before-mentioned simpler manures. It must, however, be borne in mind that all mixtures of this description are subject to the same standard of value as that mentioned in speaking of superphosphates; namely, that the price charged for the manure will only exceed the market price of its constituents by the cost of manufacture and the amount of a fair profit. Many of these compound manures found in the market are equal to this standard, and fully worth the money asked for them, the proportion of fertilizing materials they contain being even greater than could be obtained by the farmer at the same price in any other form.

On the other hand, it must be remembered that mixtures of substances are constantly met with called "fertilizers", and all sorts of high-flown names, whose value is but a fraction of the price demanded for them, and which too often consist of materials altogether worthless. Compounds of this sort, of alleged marvellous fertilizing power, are often sold in small packets at extravagant prices. It need scarcely be said, articles of this description are simply contrivances of designing speculators for fleecing unsuspecting persons. It may be recollected, as a rule without exception, that any manure possessed of extraordinary fertilizing power will contain in corresponding quantity those materials on which the luxuriant growth of plants is known to depend, as no magic is yet discovered for making plants grow by any other means. Thus we perceive that artificial manures are possessed of peculiar merits altogether distinct from those of farmyard manure; and that while these substances are highly useful—we may say indispensable in the present system of farming—they can never be used in place of farmyard manure, but always as additions and auxiliaries to this material. The manure produced on a farm should contain all the fertilizing elements extracted from the land by the crops raised upon it, with the exception of those contained in the grain, cattle, or other produce sold off the farm. Hence, if the manure made has been properly preserved, we can return to the land, in this shape, all the materials borrowed from it for the growth of our crops, except those carried away in the manner above noticed. To make good this deficiency we should employ artificial manures; since in these we possess a ready and convenient means of restoring to the soil those more essential constituents permanently removed from it by the produce sent to market. The soil of a farm may thus be regarded as a manufactory of Nature, in which, from certain raw materials, as phosphoric acid, ammonia, etc.—with those supplied by the atmosphere and water—she prepares grain, beef, mutton, and all other kinds of agricultural produce. While on some soils an inexhaustible supply of these materials (with the exception of ammonia) exists, and the business of the cultivator chiefly consists in preparing the ground and assisting Nature to avail herself of such constituents, on most soils these raw materials must be supplied in the shape of farmyard manure, guano, superphosphate, or other manures. In either case, the farmer holds the position of attendant or curator to Nature, who rewards him in proportion to the diligence and skill he displays in attending upon her.

RECENT ANALYSES OF SPECIAL MANURES.

	1.	2.
Moisture	18.13	11.13
*Organic matter and salts of ammonia ...	15.70	19.20
Mono-phosphate of lime	8.18	3.21
equal to bone phosphate made soluble	(12.76)	(5.02)
Insoluble phosphates	4.17	9.13
Sulphate of lime, etc.	21.20	25 81
†Nitrates and alkaline sal s	28.60	26.34
Insoluble matters	4.02	5 18
	100.00	100.00
*Containing nitrogen	1.42	1.40
equal to ammonia	1.72	1.70
†Containing nitrogen	4.10	2.62
equal to ammonia	4.98	3..8
Total ammonia	6.70	4.88

The above are given as examples of manures containing nitrates, and illustrate the mode of stating nitrogen present in this form. No. 1 is a good barley manure, and No. 2 a corn manure in which the soluble phosphate is rather low.

THOMAS' OR BASIC SLAG PHOSPHATE.

This material, which appears to find increasing favour, is a by-product in steelworks where the basic process is used. From the accompanying analyses it will be seen to have a considerable proportion of phosphoric acid; in addition to this it also contains much iron, some of which is in the metallic state, although it appears usual to remove as much of this as possible by passing the slag over a system of magnets; a good deal is also present as ferrous compounds. One would naturally think these facts constituted rather serious drawbacks; in practice, however, they are said not to interfere materially with the growth of crops. To obtain satisfactory results this phosphate must be exceedingly finely ground, a common standard being to cause it to pass through a sieve having 10,000 holes to the inch. The form of combination assumed by the phosphoric acid and lime in this manure is stated to be of an exceptional character, the proportion of the latter being greater than in ordinary phosphate of lime, which is believed to render it more available in the soil than raw mineral phosphate. Much free lime is also present, and some quantity of soluble silica.

We should consider it to be especially useful for reclaiming boggy or sour land, and for grass generally, but cannot consider that for most purposes it compares favourably with superphosphate.

Both buyers and sellers of this material should always bear in mind its very variable character, especially when derived from unknown sources, for which reason it is desirable to have a careful analysis as the basis of any transaction.

RECENT ANALYSES OF BASIC SLAG PHOSPHATE.

	1.	2.
Phosphoric acid	14.40	16.60
equal to tribasic phosphate of lime... ...	31.43	36.24

Home-made Manures.

As regards the making of superphosphates and other manures by farmers, a few words should perhaps be said; but beyond the mixing and sifting of dry materials, as for the better employment of nitrate or of guano, and as a preliminary operation to the application of other manures, we would not recommend farmers as a rule to proceed, but may here quote a recipe from the author's *Lecture on Superphosphate*, for the benefit of those it refers to.

"If, however, any farmer out of curiosity should desire to try his hand at superphosphate-making, the following directions may be followed; but it must be understood that I by no means recommend this process to manufacturers for the making of superphosphate generally.

"For a ton of bones, which should be ground small and boiled, to extract as much as possible of the fat, the following quantities of acid and water may be used, viz., 740 lbs. white oil of vitriol, or 850 lbs. brown acid; this is about equivalent to 41 gallons of the former and 50 gallons of the latter.

"1,000 lbs., or about 100 gallons of water, are divided equally, one part being used to moisten the bones and the other to dilute the acid. The latter operation should be carefully performed in a large bucket or tub, pouring the acid in a small stream into the water, the latter being well stirred meanwhile. The bones should be thoroughly moistened with water from a garden watering-can, and left for two or three hours, or longer, to get well soaked. The mixing should be made in a wooden trough or large tub. If a sufficiently large vessel cannot be had to receive all the materials at once, it may be done in a smaller one, using successive and proportionate quantities of bones and acid; or the mixture may be made, but not so well, on the ground (with a hard clay surface if possible), a ring being made with ashes (black or red, about equal in weight to the water used), to prevent the liquid flowing away. The acid should be gradually added to the bones, the whole being well stirred with a wooden rake to insure uniform admixture. As soon as the acid is all added and the mixing completed, the greater part of the ashes may be thrown over the mass, and the whole allowed to stand for some days. The heap may then be opened, and the whole of the ashes well incorporated with it; the mass being then allowed to stand again for a week or so, and if not then sufficiently dry, may be broken up again and re-made into a heap, with thin layers of fresh dry ashes. By this means a superphosphate may be got perfectly dry and manageable, the large addition of ashes being, of course, no great objection when, as we are supposing, it is to be consumed on the farm where made.

"A superphosphate made in this way, with the first quantity of ashes mentioned, was found to contain 12.27 per cent. of soluble phosphate, and nitrogen equal to 2.07 of ammonia."

Although the above recipe for the home preparation of dissolved bone, or, as it should now be more correctly termed, vitriolized bones, is allowed to stand, we should not, as a rule, advise the making of any manure involving the use of vitriol, as this is nasty stuff to handle by inexperienced persons; but mixtures of dry materials, as under, can be easily made by anyone so inclined.

For small farmers, and allotment cultivators and gardeners, the following remarks as to home-made manures may be useful; but where large quantities of manure are required it will in most cases be found best to buy them in the ordinary way. We have known instances where large farmers have made manures successfully, and yet have found it more economical to buy.

In gardens where plenty of animal manure is available little else is required, but on many larger plots of ground, particularly grass land, which is too often starved, we may take it that the more manure of any suitable sort we apply the better. House-slops are a valuable liquid manure, as will be understood from our remarks on sewage ; kitchen slops are useless or even injurious from the grease they contain. The former have an additional value in assisting the decomposition of vegetable refuse in heaps, and whereby at the same time any offensive matter is removed. It may be taken as a good rule that weeds and garden refuse should be rotted rather than burned, as by the latter we lose the valuable nitrogen in whatever shape it is present. Foul turf, or refuse infested with insects, and brushwood may be got rid of by burning, and the ash furnishes a valuable source of potash, as well as phosphates, etc., as we explained earlier in the book.

The use of chemical manures in gardens is only beginning to be adopted, and is well worth the attention of nurserymen and florists ; but where they are thought too expensive for general use, a little of them mixed with ordinary composts often has a marked effect. For this purpose superphosphate (ordinary mineral, which is the cheapest form) and sulphate of ammonia are likely to be most useful. The former supplies phosphoric acid, in which the manures from animal sources are often deficient. The latter is very rich in ammonia, 1 cwt. containing more than 1½ ton of farmyard manure. It can in some places be procured at the local gas-works, and, when properly purified, is well worth its high price. It is best mixed with dry earth and allowed to lie some time, by which all free acid is removed, and then well sifted. By weighing the earth and sulphate before mixture we can better keep account of the ammonia we add in mixtures, etc. Nitrate of soda may be used in the same way, but is deliquescent, and becomes moist in damp weather.

Bones are often more easily obtainable than the above, but are very slow in action in the natural state. This may be accelerated as follows. If rough, they may be broken down with a hammer on an anvil or iron block ; they should be boiled to extract the grease. It is a common mistake to suppose this grease is of any benefit to the land ; on the contrary, it exerts an injurious effect by retarding decay. If, while damp, they are allowed to lie in a heap, better covered, they may be got to "heat" or ferment. If superphosphate is bought it may be mixed with bones in a heap, whereby the acid has a good effect upon them, or caustic lime mixed with bones will decompose them ; but there is some danger of loss of nitrogen.

Kainit is a useful source of potash, and not expensive : it is specially serviceable for potatoes. An excellent manure for this crop is one part kainit, one part sulphate of ammonia, and three parts super. One part sulphate of ammonia to two of super make a valuable corn-manure for strong land. For lighter land one of sulphate to three of phosphate may be used. Bone-meal and super, equal parts, are found a valuable manure for roots in some districts. For mangolds ammonia should be added, also common salt : say, two super, one bone-meal, one sulphate ammonia, one salt. All these compounds should be thoroughly incorporated, and further mixed with ashes or dry earth before application.

All of the concentrated manures above given can be diluted to any extent with compost or animal manure, or perhaps we should say the latter may be strengthened with the former. Of course, the more used the better the result, within reasonable limits (but a mere dash will often have a distinct effect), and by the increase in quality or quantity of crop, yield us a profit on the outlay.

Adulterated Manures.

The adulteration of manures, as indeed of all other articles of commerce (especially those in any way used as food or medicine), is a practice that cannot be too strongly condemned.

Under the name of manures all kinds of mixtures are sold, often worth but a fraction of the price paid for them, and in too many instances altogether worthless.

The frauds practised by dishonest manure-dealers consist of the diluting or weakening of standard manures, as guano, superphosphate, nitrate of soda, etc., by the admixture of less valuable or useless materials, as sand, sawdust, brick-dust, etc.; also in the fabrication of mixtures from all kinds of cheap refuse and other materials, as tanners' bark, road-scrapings, old mortar, etc. Such mixtures are brought into the manure market as new compounds, under all sorts of high-flown names, which generally indicate properties in every way the reverse of those possessed by the so-called manures they represent. Mixtures of this description are often supported by flaming testimonials, through which many persons are often induced to waste their money on these worthless compounds. It must be remembered that even genuine testimonials in support of the character of a particular manure afford no proof of its real or market value, since what may produce a good effect on one soil will not do so on others. The fertilizing effect of a manure on a soil will be just in proportion as the former is able to supply what the latter is most in need of. Hence it may happen that a soil is only in need of lime or sulphuric acid : in this case a manure containing plenty of lime or sulphuric acid is all that is requisite to enable it to produce a good crop. On such a soil a comparatively worthless mixture of gypsum or sulphuric acid in any other form will produce as good an effect as a valuable superphosphate that contains, in addition to sulphuric acid and lime, the more valuable phosphoric acid ; because in this particular case this latter material, generally so valuable, is useless, the soil already containing a sufficient supply. It is by instances of this sort that a manure often acquires a false character, and is believed to possess qualities to which it has not the slightest claim. Certain natural casualties, to which all crops are occasionally subject—as very wet or otherwise unfavourable seasons, blight, etc., which interfere with the action of the best manures—also occasionally favour the character of inferior ones, and for a time conceal their worthlessness.

Hence the money value of a manure cannot be estimated by its effects on a particular soil. Theoretically speaking, all manuring substances are equally valuable, because they are all alike indispensable to the growth of plants; for instance, silica is in this sense as valuable as ammonia, because, unless both of these substances are present, the wheat plant cannot flourish. Again, lime is as valuable, because as indispensable, as potash to the growth of nearly all plants. But the money value of these compounds is widely different, simply because the relative quantities of them occurring in nature are totally unlike; for which reason they can be procured with very different degrees of facility. While silica, lime, organic matter, etc., are abundant in most soils, and are furnished to the plants in inexhaustible quantities, the ammonia, phosphoric acid, etc., are naturally supplied more sparingly: hence these materials are soonest removed from the soil by the crops grown upon it; and when we wish to renew such constituents, we find that we can only obtain them by paying for them; and the price at which they can be procured is of course regulated by the quantity supplied in the market. The amount we can afford to pay for a manuring material is of course determined by the increase of produce we may calculate upon through its action. Thus the number of substances at present used in artificial manures is limited by the price at which they can be procured. Several salts of high fertilizing value—as phosphate of potash or phosphate of soda, nitrate of ammonia, phosphate of ammonia, etc.—would be eagerly bought as manures, could they be supplied at a price consistent with agricultural economy. By the discovery of more prolific sources of materials that can be used in agriculture, certain substances, formerly used for other purposes, find a new application in the way of manures; for instance, until the discovery of guano, or rather its importation to this country, the artificial supply of ammonia to agricultural crops was very limited, simply because all the combinations of ammonia supplied to the market obtained a price far beyond that which the farmer could afford to pay. Again, long after it was discovered that nitric acid was a valuable fertilizing material, its use as a manure was prevented by the high price of its salts : they were in demand for other purposes, and consequently were worth more money than the farmer was able to pay. But comparatively recently, vast beds of a material containing a large proportion of nitric acid have been discovered ; so that its market price is reduced, and now comes within the reach of farmers.

The means of obtaining good artificial manures have fully kept pace with the improvements in the articles themselves, for, owing to the present facilities of transport, and the practice of appointing agents by distant manufacturers, almost every market in the kingdom is abundantly supplied —so much so, indeed, as to make it difficult sometimes on the part of the farmer to know which to choose.

As in other branches of industry, competition has been the chief cause of this, and has thus benefited the consumer of artificial manures, through being, of course, the principal instrument in bringing about the improvements both in quality and price we have been speaking of.

The positively bad manures common some years ago under various high-flown names, and which did a great deal of mischief, not only by fleecing those who were unfortunate enough to buy them, but by encouraging a disbelief in the benefits of other really valuable manures, and so retarding their usefulness, are now less dealt in. This is because the knowledge of the nature of manures and their action in the soil is far more widely disseminated of late years, especially amongst the more advanced class of agriculturists, and is also due to the fact that the manure trade has fallen more into the hands of established manufacturers of stability, who carry on the business in a more open and enterprising manner. A better appreciation of chemical analysis, as the only means of ascertaining their value, both on the part of makers and buyers of manures, has also contributed to the above result; for although farmers do not individually avail themselves of analysis in the purchase of manures or of oil-cakes (which are still more difficult to obtain of good quality) to the extent it would be clearly to their interest to do, yet some of the more advanced farmers' clubs now devote a small portion of their funds to this object; and, considering the good that has been and may be thus conferred, it is obviously a wise proceeding on their part, and worthy of more extended imitation. With the view of encouraging this practice, we shall always be pleased to make special arrangements with any farmers' club or society wishing to adopt it.

Notwithstanding the fact that the supply of artificial manures is thus, on the whole, satisfactory, instances of loss, both in money and crops, through adulterated and inferior manures, are still sufficiently common to warrant a careful discrimination on the part of the buyer of these articles, for, owing to a too confiding system of business, inferior descriptions sometimes find their way into the hands of respectable firms, who may sell them at prices far above their value, although without the slightest intention of fraud, but which is not, of course, on that account less disadvantageous to the purchaser.

The following analyses illustrate samples received by us of an adulterated or inferior character. Nos. 4 and 5 are quite recent instances of manures made during the last season, which, as the results show, possess but little value.

EXAMPLES OF INFERIOR MANURES.

	1.	2.	3.	4.	5.
Moisture	14.74	7.13	30.16	13.22	18.64
*Organic matter and ammoniacal salts	25.27	18.67	27.72	29.36	17.50
Phosphate of lime	16.32	13.83	1.36	12.34	10.13
Carbonate and sulphate of lime	11.16	11.24	7.62 }	41.68	24.61
Alkaline salts	4.48	3.01	2.34 }		
Insoluble matters, sand, etc.	28.03	46.12	29.80	3.40	29.12
	100.00	100.00	100.00	100.00	100.00
*Containing nitrogen	6.45	4.34	1.02	.73	1.30
equal to ammonia	7.83	5.27	1.23	.88	1.58

No. 2 was sold as guano, and had all the appearance of genuine Peruvian, the quantity of which present in it being sufficient to impart the strong characteristic smell, and a fair proportion of the small crystalline lumps which always occur more or less in this manure. It contained, however, as will be seen, 46 per cent., or not far short of half its weight, of earthy matter in the shape of fine loam, which being very similar in colour to guano, rendered the mixture an excellent imitation of genuine guano, and would deceive the best judges by its appearance.

The sample No. 3 was a very dark-coloured material, with a strong offensive smell, and might easily be mistaken for a rich specimen by persons whose ideas of manure are vague, although otherwise well informed. It will be seen, however, that it contains about 30 per cent. of water to begin with, a good deal of organic matter, but mostly of a non-nitrogenous kind, in a state of decay (hence its strong smell, which we need hardly say is no evidence of value in manures). The amount of ammonia it yields is only about 1 per cent. ; and as it contained no other constituent of any appreciable value, and further had nearly 30 per cent. of sandy matter, its money value is considerably less than £1 per ton.

Cases of loss in this way are bad enough, but much augmented when, as not unfrequently happens, a loss of crop ensues. Naturally these fall most heavily on small farmers, who are least able to seek redress, but which should be firmly enforced and exposed when discovered by persons having the means of so doing.

A matter of some interest to agriculturists during the past year is the introduction by Mr. Channing, M.P., of his Bill for the prevention of adulteration of manures and cakes, which, for the present, is in abeyance pending the introduction of a measure with the same object by the Minister of Agriculture.

Whether such a bill is necessary or not has given rise to much discussion; for while it is true that adulteration in these articles prevails, and that the smaller class of farmers are the chief sufferers, it is said on the other hand that by dealing only with firms of repute, and submitting all bargains to a competent analyst, the farmer is well protected against fraud. It has also been bitterly remarked that protection would be better bestowed on general investors, whose moneys are often the sole means of provision for widows and children, and who are entirely at the mercy of fraudulent or careless promoters of hopeless companies, or insolvent foreign borrowers, and whose collective losses count by thousands or even millions against the farmers' tens or hundreds brought about by adulteration of this kind. Be this as it may, however, the farmer is of course entitled to protection when it can be shown he is victimised in this way, and that its prevention can be carried out in a practical shape.

At the same time it should be remembered that losses of this nature mostly arise from a too eager desire for bargains; whereas in these, as in other commodities, it may be taken that any price less than a fair one is generally accompanied with some defect or deficiency.

Mr. Channing's Bill is, we believe, founded on similar Acts in vogue in France and the States; although some of the penalties of the former—notably that of summary imprisonment—would never be tolerated here, and were therefore not included in the Bill. It is intended to be carried out on the lines of the Adulteration of Foods and Drugs Act, but many more practical difficulties are involved through the different and peculiar character of the articles dealt with, and the scarcity of analysts competent to undertake the necessary work, as this branch of analysis constitutes a speciality requiring long training and experience; and trouble even now frequently arises from analysts appointed under the Act named above being expected to deal with manures and cakes. There is also the additional expense, which would tend to enhance the market prices of these articles all round.

The chief argument, however, in favour of the measure is that buyers, who have been to the expense of an analysis and find themselves defrauded, have no redress except that afforded by an action at law, and as this remedy is often thought worse than the disease, it is not applied. This would, of course, be true in the case of sellers having no reputation to lose, but the majority of manufacturers in this trade are at present men of standing, who are always desirous of dealing fairly with their customers, and, where any lapse in quality is discovered by a competent analyst, are usually ready to allow any reasonable claim.

Mr. Chaplin's Bill, referred to above, has now been published, but will probably be considerably modified before it passes. This is only to be expected, for to frame a Bill which shall meet all the requirements of such a case is indeed most difficult, for, while wishing to be fair to one side, we run no slight risk of injuring the interests of another. Meanwhile, and supposing such a measure should never become law, we strongly advise farmers to make use of those means already at hand for their protection, and also, we feel sure, for the greater satisfaction of all well-disposed people concerned.

Nitrate of Soda (Sodium Nitrate).

This important manure differs from any of the foregoing in supplying one constituent of plant-food only, viz., nitrogen as nitric acid, the base having but little value for the purpose, and may now be considered by far the principal source of this element. In speaking of the atmosphere, we noticed the existence in the air of minute quantities of a substance called nitrate of ammonia—a salt that is found to exercise a powerful effect in promoting vegetable growth ; and it was stated that the superior efficacy of rain that falls during thunderstorms, in refreshing and invigorating plants, is, in a great measure, due to the nitrate of ammonia it contains.

Substances closely analogous to this salt are saltpetre—the principal ingredient of gunpowder—the proper name of which is potassium nitrate, and the salt now so commonly used as a top dressing for wheat, called Chili saltpetre, or, more correctly, sodium nitrate, or nitrate of soda.

Each of these salts contains a large quantity of nitric acid, or aqua-fortis—the material to which the fertilizing effect they produce is more immediately due.

As we are already aware, nitric acid in a separate state is a highly corrosive fluid, capable of dissolving metals, like silver or copper; but when combined with alkalies—as in the above salts—these corrosive properties are concealed and overcome, and it becomes a most useful fertilising material, which, like ammonia, supplies plants with the nitrogen they require in the formation of the flesh-forming compounds of food.

It is probable that most of the nitrogen received by plants is conveyed to them in the form of nitrates, and that the nitrogen contained in all animal or other substances added to the soil as manure is ultimately converted into these compounds.

Nitric acid is found in small quantities in dung-heaps; and wherever animal or vegetable matter containing nitrogen is present with much lime, under favourable circumstances, nitric acid is formed from the nitrogen of the organic matter. In this manner, large quantities of nitrate of potash, or saltpetre, can be formed artificially in nitre-beds, as they are called. For further information concerning the process of nitrification, see page 71.

In an analogous manner, the nitrate of potash found in the soil of certain warm climates, as in the East Indies, is probably formed. Large beds of a salt very similar to nitre are found in Chili—hence, the term "Chili saltpetre", sometimes applied to the nitrate of soda employed in agriculture.

Although nitrate is a valuable manure as a top dressing, or as a constituent of compound manures used for this purpose, it cannot with advantage be used in the place of phosphatic manures or of the nitrogen from animal matter, or to some extent of that from sulphate of ammonia, which have a separate and distinct action. We have even heard of it being used for dissolving with phosphate by acid, with the view of supplying nitrogen in the manure, but which, it need hardly be said, would result in an almost entire waste of its virtues. Theoretically, it is incorrect to mix nitrate with superphosphate at all, but there is no practical objection to so doing in moderate quantity if the superphosphate is in dry condition, or if a drier be also used. A practical objection to such a mixture is the tendency of nitrate to deliquesce and give a wet appearance. A manure of this character was submitted to us some years since, and was made of equal parts nitrate and phosphatic guano, and of course gave a high result, but was not a success, chiefly from this cause. The question has lately been put to us whether if nitrate be used in a compound manure, in conjunction with bones and sulphate of ammonia, its nitrogen will be credited to the manure by the analyst. To this it may be answered, as we have already remarked, that it is easy to overlook the nitrate in the analysis, as it is not included in the ordinary nitrogen determination, but requires a special operation, and cases of the kind in which the nitrogen in the manure has been returned too low are by no means rare. This constitutes another objection to the use of nitrate in such a way, although it may be met by the sender mentioning its presence, for as a component of corn manure for spring use, this salt is especially efficient.

For the reason just given nitrate of soda is used as an ingredient in some of the prepared corn manures. It is also used with good effect in grass manures. A useful spring dressing for grass consists of equal parts of nitrate of soda and superphosphate, applied either in conjunction with about an equal weight of salt or with the "compost" often used for grass land. The following passage regarding this compost and other manures for grass is quoted from the author's *Food Feeding and Manures.*

"Mild, diluted manures seem to be those best suited for this description of land; however, nothing can be better than the composts usually applied to this purpose, provided they contain sufficient fertilizing materials in addition to the earthy matters which necessarily form the chief part of such mixtures, and which serve no other purpose than to equalize and temper the more active ingredients, just as, to use a familiar simile, ardent spirits are less injurious and more agreeable to the human palate when diluted with water. But, unfortunately, the mixtures supplied to grass land under the name of composts often consist of the merest rubbish alone, with scarcely any fertilizing constituents. Moreover, the vegetable refuse used in the formation of such compost is sometimes imperfectly rotted before addition to the grass, so that the roots and seeds of weeds from the cleaning of other land become thus conveyed to the pastures, and may do more mischief than the scanty manure does good. Whatever materials we may use in the formation of composts, sufficient manure, either as ordinary dung or in the shape of drainings (which are well suited for this purpose), should be added, both to effectually rot any vegetable remains, as well as to impart virtue to the mass.

"Liquid manure is also, when available, an excellent medium for manuring grass land, as the fertilizing elements thus supplied are very equally distributed, and at once fit to be made use of by plants; indeed, the quantity of grass that can by this means be procured is in some places almost incredible, and worthy of a more extended imitation."

X 2

EXAMPLES OF ANALYSES OF NITRATE OF SODA.

	1.	2.	3.
Moisture	1.60	1.62	1.46
Nitrate of soda	96.21	94.93	34.60
Chloride of sodium	1.55	1.40	61.50
Sulphates, etc.	.64	.63	2.20
Insoluble matters	traces	1.42	.24
	100.00	100.00	100.00
Refraction...	3.97	5.07	65.40

No. 1 is an excellent sample, being rather above the average quality—the standand proportion of impurities (refraction) is 5 per cent.

No. 2 was a discoloured sample; the analysis, however, proved it to be much better than anyone might have supposed judging from its appearance.

No. 3 was an adulterated sample, having, as we see, nearly two-thirds of common salt present; this would therefore be worth only about one-third the market price of the genuine article.

From the foregoing analyses we see that, like all other artificial manures, nitrate of soda is sometimes found adulterated. In most cases this is effected by means of cheaper salts of similar appearance, as, for instance, common salt, or sulphate of soda, etc. As these salts are all crystalline, and in some other respects resemble nitrate of soda, their presence cannot be detected by any means short of an analysis.

A barefaced instance of fraud under nitrate of soda was discovered by us during the past season. A sample was offered as of slightly inferior quality at 7*l.* per ton. It contained no nitrate at all, but consisted of ordinary washing soda powdered up and put through a sieve of about the size of ordinary nitrate crystals, which it resembled, though very light coloured, which is often the case with inferior samples.

Sulphate of Ammonia, and other Sources of Nitrogen.

The first of these is similar in some respects to the foregoing substance, but under certain conditions has advantages over it, chiefly on account of the greater retentive power the soil possesses for ammonia—a property of the highest value in our uncertain climate. We should, therefore, if we feel in a position to judge the probable character of the season, make use of sulphate of ammonia when rain may be expected and nitrate of soda if the weather is dry and settled, while at the same time the rule of applying small dressings at short intervals is beyond doubt an excellent one for avoiding waste in the use of either where circumstances permit us to carry it out. The value of sulphate as a manure is great, and it is especially useful as an ingredient of compound manures.

This value is, however, in common with that of all purely nitrogenous manures, entirely dependent upon the proportion of this element they contain—we are leaving condition out of consideration for the moment—in sulphate the percentage given as ammonia equals 24 to 25, its composition being fairly regular.

Other special sources of nitrogen are found in azotine, dried blood, shoddy, hair, leather, hoof and horn waste, sud cake or shoddy meal, soot, etc. These differ greatly from the materials already mentioned, and also amongst themselves in the rapidity of their action on the soil, their insolubility at once indicating a most important difference. Generally speaking, however, this condition is considerably modified before using them on the land, for with the exception of various special uses, manuring hops with wool waste for example, they are not directly applied, but are mixed with phosphatic materials and treated with acid. In addition to their insolubility the nitrogen present is not in a form readily assimilable by plants, and must undergo certain changes in the soil before it becomes available.

Sulphate of ammonia has also to be changed, but this is accomplished more rapidly.

Within certain limits, however, we must not by any means consider this slowness of action a disadvantage, for in many cases it is important that nitrogen should be yielded little by little, and in such instances these may decidedly claim preference over the soluble salts. Therefore we are mistaken if we suppose the two classes may be used interchangeably for one and the same purpose. Speaking in detail of the manurial value of these materials, we may consider that dried blood, providing it is not over-dried, and azotine—a peculiar and valuable preparation, containing respectively about 12 and from 7 to 8 per cent. of ammonia (nitrogen equal to)—occupy the first place when we remember both the amount of nitrogen they contain, and the greater rapidity of its reduction to a form suitable for plant-food. Horn and hoof waste, yielding a high percentage of ammonia, if not overheated, would seem to provide a useful source of a gradual supply of nitrogen, while shoddy, with 6 to 9 of ammonia and shoddy meal or sud cake, supplying nitrogen equal to from 3 to 4 or 5 of ammonia, need very thoroughly treating with acid before they can as a rule be considered useful as manure. Leather, unless most carefully prepared by a special process, when it becomes much more manageable, cannot be recommended.

POTASH COMPOUNDS.

The salts of potash are often of great value to crops when the land upon which they grow is deficient in this material, although it cannot be considered so generally necessary as phosphoric acid or nitrogen, for very many soils have a sufficient supply for ordinary purposes. For special uses it is, as we have observed, employed as one of the constituents of compound manures: the salt most largely used is called muriate of potash or potassium chloride, the commercial product having about 80 per cent. of the pure material.

Kainit is a mixture of several salts of more or less value to the agriculturist, the most important being a salt of potash; the magnesia present is also probably useful in some cases, but like the remaining constituents, is not generally taken into account. This material is usually found to contain potash equal to from 23 to 25 per cent. of sulphate of potash, which latter salt is itself also used; the composition of the crude material is, however, very variable.

Refuse and Miscellaneous Manures.

Having now considered the more valuable nitrogenous and other manures, let us proceed to describe a few cheaper refuse substances, that are used for such purposes, which possess some of their qualities in a less degree.

An ammoniacal manure in common use is soot. This substance is chiefly useful on account of the ammonia it contains in the form of salts. The smoke of lamps and coal fires consists of minute particles of unaltered charcoal, with other intermediate products of combustion. All the charcoal, or carbon, of fuel that takes part in the actual combustion is converted into carbonic acid gas, as stated in a previous chapter. But when much carbon is present in a fuel that burns with flame, a great deal of this element is carried off in the shape of smoke: from this smoke the carbon is readily deposited upon any cold object. In this finely-divided shape carbon is technically called lampblack, and is an article of extensive manufacture. The soot that accumulates in our chimneys, where coal is used for fuel, is an impure kind of lampblack. It is to these impurities, however, that soot chiefly owes its agricultural value. In speaking of the sources of ammonia it was stated that one of them is ordinary coal. This material contains variable quantities of nitrogen in organic combinations—when the coal is burnt, this nitrogen passes off in the form of ammonia. Coal also contains sulphur or brimstone. When this substance is burned in the coal, a part of it is volatilized in the form of sulphurous acid, which, meeting with the ammonia simultaneously liberated, effectually fixes and retains it in the soot.

We may satisfy ourselves of the presence of ammonia in soot by testing it with lime in the manner described when speaking of guano: by such treatment the soot will evolve the well known strong smell of this gas. The quantity of ammonia present is from about 2 to 5 per cent., as the composition of this material varies greatly, the percentage of dirt and cinders being different in every sample. When soot is easily obtainable at a reasonable price the farmer would be wise to avail himself of the opportunity, and this is true of all materials having any real value as fertilizers, only the purchaser should use proper precautions to see that he gets his money's worth for his money, because the risk of giving a low price for an article and yet paying very dearly for it is considerable. Especially is this the case if we rely upon merely physical evidence to form our judgment, such as that furnished by smell, appearance, feeling, etc.: these matters being important enough sometimes, but they can never give us information, which is only to be obtained by careful analysis.

Gas Liquor.—While speaking of soot, and remarking that its value as a fertilizer depends on the presence of certain compounds arising from the combustion of coal, we are naturally reminded of the use, as manure, of the same compounds, formed on a large scale in the process of gas making.

When coal is heated in closed vessels for the purpose of converting it into gas, much of the nitrogen it contains passes off in the shape of ammonia, together with the other gases simultaneously produced. In undergoing the process of purification to adapt it for illuminating purposes, the coal gas is deprived of this ammonia and other impurities, part of which are retained by water through which the gas is made to pass. This water is technically called "gas liquor", and is the source from which most of the ammonia found in commerce is prepared. This gas liquor consists of water containing variable quantities of ammonium sulphide, carbonate, etc., dissolved in it with other matters. To obtain this ammonia the gas liquor is evaporated with some strong acid, as sulphuric acid. By these means the volatile alkali is fixed, and when purified constitutes sulphate of ammonia—a substance often used by the farmer for the same purpose for which he uses guano or nitrate of soda, a practice to which reference has already been made. This salt is also largely employed by manure-makers in the preparation of wheat manures, grass manures, and other mixtures of the sort.

In districts in the immediate neighbourhood of gas-works, the gas liquor itself is occasionally used as a manure, and by judicious management may be employed to advantage upon grass land and other crops. The use of this fluid as a manure is, however, attended with a certain amount of risk, since, unless it is sufficiently diluted with water before application to the land, it is liable to produce a contrary effect to the one desired; in other words, it is apt to injure the crop by the sulphur and tarry matters present. This effect is also partly due to the salts of ammonia it contains, which always exhibit an injurious effect on vegetation when too bountifully supplied. It must, however, be remembered—in extenuation of the character of gas liquor as a manure—that guano occasionally produces the same injurious effect, if carelessly applied. The proper way to use gas liquor is to largely dilute it with water, and in this weak state supply it to the land by means of a liquid manure distributor. The employment of this material for such purposes is, of course, limited to the districts in the vicinity of gas-works; since, on account of the large proportion of water present, its conveyance to any distance is impracticable, the expense of carriage soon amounting to more than the whole mixture is worth.

GAS LIME is also occasionally employed as a manure; but, generally speaking, its use cannot be recommended as, although cheap, it is always risky. We mention it in this place because a belief is common that this substance contains more ammonia than gas liquor. It need scarcely be said this is not the case, simply because caustic or quicklime—the prevailing ingredient of gas lime—expels ammonia from any of its combinations. It is on this fact that the test for ammonia, described in an early chapter, and to which we have several times referred, is based: hence gas lime cannot—neither does it—contain any appreciable quantity of ammonia. The use of this substance in localities where it can be procured at a very cheap rate, as a source of lime and of sulphuric acid, may be tried. We should not allow the material to come into contact with plants until it has been exposed to the action of the weather, otherwise an injurious effect will follow.

Rape Dust is a material used as manure, and contains from 5 to 6 per cent. of ammonia (nitrogen equal to) with but small quantities of any other fertilizing constituents. The application of this substance to the soil is a very good way of using some classes of the cake which are quite unsuited for feeding purposes; indeed, particular watchfulness is always necessary in purchasing this variety of food when it is intended for stock. This dust is considered by some to have a special value as a cure for wireworm.

The blood of animals is well known to be a most powerful manuring substance. It contains nearly all the essential constituents required for the growth of plants: hence, if this material can be economically procured, its use as a manure may be recommended; also butchers' offal and similar animal matter.

Gypsum is the mineralogical name of the substance popularly known as plaster of Paris, the chemical name of which is calcium sulphate. As the latter name indicates, it is composed of sulphuric acid and lime; and since both of these substances, especially the former, are occasionally deficient in soils, the application of gypsum is often attended with good effect on the land. Gypsum is found to exert a peculiarly favourable influence on all leguminous plants, as clover, peas, etc. Towards these plants, this salt often acts as a useful manure; and in soils deficient in sulphuric acid and lime, the addition of it to crops of this kind is to be recommended.

Another valuable property of gypsum is its power of fixing ammonia. It is found that when the volatile carbonate of ammonia meets with gypsum or sulphate of lime, a mutual change of composition results, and sulphate of ammonia and carbonate of lime are formed. Sulphate of ammonia being a permanent salt, the ammonia is now fixed or safely preserved from loss by volatilisation. As our readers are now fully aware, the special application of gypsum is unnecessary when superphosphate is employed.

COMMON SALT (sodium chloride) must not be omitted in a list of substances used as manures, although its claim to this rank is not so well established as those of the materials hitherto described. A great diversity of opinion seems to exist respecting the manurial value of salt; while some persons extrol its use in extravagant terms, others, apparently well able to judge, as strongly condemn it. We suspect these apparent discrepancies in the results of manuring with this compound might be explained in a manner similar to that which so happily sets things at rest in the fable of the chameleon. Salt is known to act very differently on different soils. Where salt is absent in the soil, its artificial addition has been known to produce striking effects; but as in most cases the soil already contains enough of this substance, a further quantity is followed by no good result. However, the use of salt as an occasional manure, as a means of destroying insects, and for other purposes in agriculture, is certainly to be recommended. Salt, or its elements, are found in nearly all cultivated plants—from this we infer that its presence in the soil is necessary to their healthy growth; it is also a constant constituent of milk. It has been noticed that the rain which falls in any open part of the country generally contains traces of common salt: this is supposed to be derived from the sea, in the manner before noticed in speaking of salt as a constituent of the soil.

The plants that require most saline matter are bulbous-rooted plants, especially mangels, which are often benefited by a dressing of salt, in addition to the superphosphate generally supplied to this corp. For this reason the manures sold as special manures for mangels, generally contain a considerable proportion of that substance. Salt is also admirably adapted for diluting the more valuable manures, as guano, nitrate of soda, etc.

Application of Manures.

It has been mentioned that the mechanical qualities of manures or their physical condition, as regards dryness, uniformity, and pulverulence, are points of great importance, and that in these respects almost as much general improvement has been made of late years, as in the proportion of soluble phosphate or other chemical qualities. Many otherwise superior manures would, however, still admit of improvement in these matters.

The value of these properties is discovered more particularly in the application of manures, which cannot be properly carried out without them, and so important is it that the fertilizing elements of manures shall be so placed in the soil as to allow them to exercise their full effect on the plants of the crop, that a good mechanical condition will often determine the practical superiority between two or more samples otherwise much alike. In fact, a manure which is chemically deficient, may, by possessing excellent qualities in this respect, actually gain a character for higher value in the field; thus showing, not that chemical properties are of secondary importance, as we might at first sight conclude, but that the physical characteristics above spoken of, are a necessary adjunct to allow of their due effect on the land, and without which a manure will compare unfavourably with others in which this point is better attended to.

It is true that extra care in application will, to a great extent, compensate for an imperfect physical condition, but we are of course supposing that all manures are treated alike in this respect, with as great an amount of care as can practically be bestowed.

The above must needs be the case if we reflect that the same quantity of soluble phosphate will better nourish a turnip plant, if distributed in such a manner that the whole of its root-fibres are benefited, than if placed merely in a few adjacent spots where comparatively few can reach it. Moreover, in the latter case, the few roots so supplied may get too much (for all the essential constituents of manure are objectionable in excess), and thus suffer injury, for a time at least, instead of benefit.

The first condition therefore necessary to allow of the manures we purchase having their full effect in developing the crop, and consequently also our profit, is that they shall be evenly and thoroughly disseminated through the soil, and to this end it is most desirable that the manure shall be supplied by the manufacturer in a state of fine powder or admit of being made so without trouble when mixed with some dry material just previous to application (for the best manures if kept any length of time in bags are apt to get lumpy; but such lumps can be easily broken down, and differ altogether from those arising from badly prepared mixtures). It is sometimes said that the action of rain and moisture is sufficient to diffuse the constituents of manures in the land without our troubling much about it; but although these natural agencies do assist our efforts in this way, we should rely on them only to complete our imperfect work, as, if we consider the minute quantity of manure we add compared with the bulk of the soil, we perceive that a very extensive natural distribution would be requisite to compensate for such neglect on our part; and that such natural distribution is not under ordinary circumstances sufficient, we might safely conclude from the superior crops which may be obtained by a little extra attention in this respect. The preparation of the soil also by judicious previous management and thorough cleaning, etc., is, it need hardly be said, an essential preliminary to the above.

The mixing of manures with some dry material when about to be used is an excellent practice, and one that might often be extended with advantage, as it affords the best practicable means for carrying out the above theoretical requirements, which are well illustrated in rich garden mould, or the "maiden earth" of old pastures, in which all the elements of fertility are abundantly present, but in so perfect a state of admixture as to defy detection, except by suitable chemical tests.

Ashes, either black (coal ashes) or red (burnt earth and weeds), do well for this purpose if properly sifted; or even dry earth beaten down or well sifted may be substituted. The mixture is best effected by turning the manure out of the bags in alternate layers with the ashes (using two or three times as much, or even more, of the latter) in a flattened heap, and afterwards putting the whole through a screen, cutting vertically into the mass, and if time can be spared, it will be labour well spent to pass the mixture again through a finer sieve, pulverizing the manure and soil or ashes well together—not too violently in the case of superphosphate, which is apt to get pasty by pressure.

It is well known that superphosphate has acquired its importance chiefly as a manure for turnips and other root-crops, which under nearly all circumstances it is found strikingly to benefit, and this depends largely upon the care bestowed in application. As these crops all require an abundant supply of easily available phosphate of lime, and as about 33 lbs. of a superphosphate with 27 per cent. of soluble yield as much of this fertilizing element as about a ton of well-rotted farmyard manure, it needs no further evidence to account for the above fact, which a longer practical experience on all sides only tends to confirm. Hence the universal popularity and uniformity of opinion as to the merits of superphosphates.

When used in conjunction with the bulky fertilizer just named, a more perfect manuring is of course effected than when the superphosphate is used alone, although on a vast number of soils the latter practice is found to yield the heavy and sound crops of roots always so much to be desired. In the former case 2 to 4 cwt. per acre is a good dressing; in the latter, 3 to 5 cwt. may be used with advantage.

For grass-land also superphosphate is now more freely used, and with good results. In districts where bone-dust is still purchased for application to grazing land, the substitution of this manure for a portion of the bone, say three-quarters to half, is found to give a more satisfactory result, and often at a saving of cost. It not only supplies the grasses with more available phosphate of lime, but the sulphate of lime, which, as we have seen, it also furnishes in greater quantity, is calculated to improve the herbage of pastures by encouraging the development of clovers.

The extreme richness of guano in ammoniacal compounds may constitute a practical drawback, since, unless great care be exercised in its application, or even with this care in unfavourable seasons, these compounds yield no commensurate results, simply for the reason that they have no adequate opportunity of exerting themselves, so to speak: hence a manure with a considerably smaller amount of ammonia, and costing much less, would give as good and perhaps better results. The use of guano in such cases is, there fore, like employing skilled labour to do unskilled labourers' work.

In saying this, we do not mean that Peruvian guano is not worth the price charged for it; on the contrary, we believe it to be still one of the best sources of nitrogen for agricultural purposes at present available, but that its application to the land, in its natural state, is not the best use we can make of this remarkably concentrated fertilizing material.

Peruvian guano contains too little available phosphates in proportion to the nitrogen present, even for corn crops, on the great majority of soils; hence its practical effect will be enhanced by increasing the proportion of this constituent, which is most chiefly accomplished by supplying soluble phosphate in a good superphosphate; this admixture can be carried out with little trouble by the farmer himself, and will be amply repaid by the saving effected.

The use of superphosphate with guano has the further advantage of leaving the land in a better condition after the crop than when guano alone is used. This must needs be the case if we bear in mind the extra drain upon the soil to supply phosphates to a crop manured with a nitrogenous manure (although guano supplies a small amount of phosphates, and is superior on this account, to a purely nitrogenous manure). It may also be said that the barley crop should make use of the phosphates left over from the root crop, as it does in ordinary cases; but the fact of a direct application of manure to the crop being found advantageous, would show that it does not get enough in this way, and is an argument against giving more manure, or such constituents of manure, to the root crop, than it is likely to make use of during its growth.

In using guano as a top dressing for wheat, especial care should be taken in preparing it for application to the land. The hard lumps should be broken, and the whole substance reduced to fine powder by heating and sifting; further, it should be mixed with two or three times its weight of ashes or dry earth, and thoroughly incorporated as already pointed out. The object of mixing with some other substance, as ashes or earth, is simply to insure a more even distribution of the guano over the soil; and the better this is effected (by whatever means), the greater will be the benefits conferred on the crops. This uniform distribution over the land, so essential for the successful employment of all artificial manures, is the more necessary in the case of guano; since by neglecting this precaution, the larger lumps are likely to "burn" the plants, and thus do more harm than good when applied to a crop.

In using ammonial manures for corn crops, it is a good plan as a rule to sow the manure broadcast and have it lightly harrowed in previous to the seed being drilled. When applying top-dressings, wet weather is, as well known, the most favourable, the precautions concerning distribution being in such cases especially requisite; it is also a good plan to allow such manures to lie for a few days after being mixed with earth, etc., before application. Amongst the many useful and ingenious agricultural implements introduced in recent years, the "Strawsoniser" is one of the most interesting by means of suitable arrangements atmospheric air is made to distribute either liquids or solids in a very finely divided condition, in any direction, and to a considerable height, points of special value in dressing hops, fruit trees, etc., one form is adapted for applying manures, although it is probably more suited to some kinds, than to others, for this purpose.

Value of Manures.

As regards the valuation of manures, it is sometimes sought to arrive at this by means of a scale of unit values, as they are termed, or the price of each point of their constituents. In the former edition of this book it was not thought desirable to give any such values for the reasons mentioned below, and the same course will now be adhered to. Some of the circumstances, however, affecting the money value of manures, may now be considered.

Such scales of values are of little use, for the following reasons: 1. That they have always the drawback of becoming obsolete as soon as any material change occurs in the market prices of manure; 2. It is almost impossible to devise any scale that shall be generally applicable: they are, therefore, very apt to mislead, especially in the hands of persons with insufficient knowledge of the subject; 3. Another objection to such scale is the fact that the constituents of manures vary in practical value according to the sources from which they are derived. Thus, it may happen that the most costly item, viz., nitrogen, may exist in the manure in a form which is quite inert and incapable of ministering to the nutrition of the plant. Or, further, it may occur in a form positively hurtful to vegetation, and yet be shown in the analysis; again, it may be present in a form that is not capable of estimation by the ordinary nitrogen determination, and unless specially looked for will then be overlooked by the analyst altogether. And, again, the insoluble phosphates may exist in several forms of varying usefulness as plant-food, either as guano phosphate, reverted or precipitated phosphate, bone phosphate, slag phosphate, mineral phosphate, and yet all show alike in the analyses. Hence it may happen that an inferior manure, when valued by such a scale from the figures of the analysis merely, may appear to be worth more than another sample costing more to make and in every way of superior merit. Of course a chemist of sufficient experience can, in making the analysis, form a pretty good opinion of the sources from which the constituents are derived, and this is sometimes almost as important as the figures of the analysis itself.

But, although the chemist should be able to give a correct analysis, or the percentages of the constituents on which its value depends, and to say whether these are derived from bone or what not, he should not be expected to give a money value, as it may be fairly questioned whether a chemist, however able, can be accepted as an authority on a purely commercial matter based upon the principles of supply and demand, such as this. We have always held that it is not the province of the analyst to fix the value of the manure he analyzes, and never do so ourselves unless specially requested in cases of importance, and are informed of all the circumstances of the question. The most that is usually done in this way at present by the best authorities and ourselves is to give an opinion of the value, whether good or not, when the price is mentioned. This is chiefly because it is found that the prices of manures vary much in different districts according to the facilities existing for carriage, or other circumstances which may here be noticed.

Further considerations which affect the value of manures, apart from carriage and nearness to the factory, are quantity bought, and especially the question of credit. It would be obviously incorrect to compare the prices of those supplied for cash and "ex-works" with any supplied by dealers, who have not only to wait a long while for payment, but who also by so doing in these hard times run the risk of bad debts. Of course, if the buyer goes to market with money in his hand, he has as great an advantage in buying these, as other commodities, and is entitled to get the benefit of it, and can only blame himself if he does not. The market price of an imported manure supplying nitrogen only, as, for instance, nitrate of soda, of course, also influences to some extent the prices of manures generally; but we must not because, from peculiar circumstances, this article is exceptionally cheap, take it as a standard for manufactured manures, in the production of which considerable outlay is involved for labour, machinery, interest of capital, etc.; which is much the same whether raw materials are comparatively dear or cheap.

Condition is also an important point in the valuation of manures, and one on which we have always laid great stress. Although it may be said all marketable manures are assumed to be in good condition, and that a clause in most contracts provides for this, yet this expression is in reality a relative term, and those samples in which it is made a point of special attention are in our opinion worth more than others in which the condition is only passable. Nothing is more striking to a chemist who deals with many samples from widely divergent localities than the difference presented by manures, of perhaps similar chemical composition, in this respect. The condition of manures, especially those of higher quality and price, would often admit of improvement, but it of course adds to the cost of manufacture by additional labour, greater loss of weight by drying, etc., and it is urged that buyers would not be disposed to pay any more for this, yet it would be well worth their while on account of the more effective action the manure would exercise on the crop.

To summarise the above remarks, the simplest and safest course for the farmer to adopt is to buy with a guarantee on the best terms he can get, and to have the bulk tested by a competent chemist. It is only fair to sellers generally that this should be done, as bargains are sometimes made on the assumption that they will never be put to the proof of analysis.

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THE END.

BRADBURY, AGNEW, & CO. LD., PRINTERS, WHITEFRIARS.

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