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A
POPULAR TREATISE
ON
AGRICULTURAL CHEMISTRY.
FOR THE USE
OF THE
PRACTICAL FARMER.

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A

POPULAR TREATISE

ON

AGRICULTURAL CHEMISTRY:

INTENDED

FOR THE USE OF THE PRACTICAL FARMER.

BY

CHARLES SQUAREY,

CHEMIST.

PHILADELPHIA:

LEA & BLANCHARD.

1842.

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TOYAL TREATISE

AGRICULTURAL CHEMISTRY

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PREFACE.

THE reasons which have induced me to publish the following treatise are, a desire to supply a want extensively present amongst Agriculturists, for such general knowledge connected with chemistry as may assist them in their various operations, and also the belief that no work of the kind at present exists, in which the subject chosen is either so fully explained or so well adapted for general perusal.

Until a very recent period, great doubt has existed amongst all writers on Agricultural Chemistry, as to the manner in which plants assimilate the matter composing their structure, not to mention the source from which these matters are derived. In the following pages I have endeavoured to explain these hitherto mysterious operations of nature, in such a way as to be of easy comprehension to all who will take the trouble to investigate the subject.

I must, however, disclaim all merit to myself for any discoveries on the subject, all the knowledge I possess has been derived from the works of Davy, Liebig, Daubeny and Johnson; and to all those who may wish to pursue

this science farther the above works are confidently recommended, especially Liebig's profound work "On Organic Chemistry, as applied to Agriculture," which contains all that is at present known on the subject, and in which the important discoveries announced are only equalled by the happy manner in which they are illustrated.

It must be permitted to me again to notice that my object in compiling the following pages, has been a desire to convey such information to the Agriculturist as may be found on trial to assist him in his pursuits, and to explain the rationale of some of the processes nature employs in the Vegetable Kingdom—with what success, it is for the reader to determine. With this intention, and this only, have I thrown together the following matter; and the little merit, if any, to which I may be entitled, must arise from the circumstance of my having in some measure simplified a subject, which, in its usual form, is too abstruse for the general reader.

Salisbury,
November, 1841.

AGRICULTURAL CHEMISTRY.

CHAPTER I.

INTRODUCTION.

The subject of the following treatise, is an endeavour to explain, in a familiar manner, the processes nature carries on in the assimilation of the various substances employed in the growth and nutrition of plants.

Until a very recent period the consideration of this subject has been too generally deemed, if not altogether beyond the range of the agriculturist, at all events, as so distantly connected with him, as to be of little direct importance. And although at various periods men, eminent for their talents, and for the successful application of those talents to agriculture, have called the attention of the public to this subject; their endeavours have too often been of little avail, and the application of science to agriculture has been almost entirely neglected.

Now, however, we date from a new era. A variety of circumstances have of late combined, to compel a greater attention on the part of all

classes to this important study. And the result is, that agriculture as a science has advanced with rapid strides, from darkness to comparative light; and from being the occupation of the lowest class in society, to one that is regarded, and justly so, as affording a field for the employment of the highest intellect; and happily also one in which the greatest exertions may be the most beneficially employed.

The impetus that this science has received may be safely committed, for its farther improvement, to the energy that now pervades the agricultural classes, in the full assurance that no exertions will be spared to carry it out to the fullest extent. The only thing necessary is to convey such information to the agriculturist, as shall tend to elucidate the operations of nature, and thus direct his energies in the right path.

It has hitherto, unfortunately, been too much the habit to consider a knowledge of chemistry necessary, only to those connected in some way or other with the practice of medicine. That such an opinion is founded in error few, in the present day, will be disposed to deny—but when we reflect that no change of any kind in any substance whatever, organized or unorganized, can take place, without such change being governed by chemical laws,—it will be at once admitted, that the study of chemistry is absolutely essential to enable us to understand either the bodies themselves, or the changes they may undergo.

Chemistry, is indeed the universal science;

It concerns every one, and every one ought to study its principles. To every branch of the manufactures of this country, this knowledge has been of the most essential importance: overcoming difficulties hitherto deemed insurmountable; opening new sources of employment, where none had previously existed; improving others to such an extent, that the different productions would scarcely be recognised as belonging to the same class, and lastly, doing all these things so much better and so much cheaper than by the old processes, that the national wealth has thereby been immensely increased, and comforts and even luxuries have been brought within the means of all classes.

It can hardly be necessary to cite examples in which chemistry has produced these results. We have only to look at the various manufactures of iron, glass, porcelain, the powers of steam, and galvanism—destined to surpass steam in its effects, the discovery of the Davy lamp, &c. to be convinced of the benefits chemistry has conferred on mankind, and of its importance as a general study.

And if this knowledge is beneficial to the generality of persons, of what paramount importance must it be to the agriculturist, whose every act entails a chemical operation, and who, unless he is enabled in some measure to understand the cause and effect of these changes, will be pursuing his avocation almost by chance, or at least without the means of availing himself of many advantages that may

offer; and farther, when we consider the important interests that are committed to the cultivator of the soil,—that from him and his exertions all earthly beings derive their support, either directly or indirectly; that the productions of the earth constitute the vast majority of the luxuries and comforts we possess; that commerce depends almost wholly on agriculture, in its various branches, for its support; that the happiness and comfort of millions is dependent on the production of the earth, and that human happiness is increased or diminished as the supply of food is abundant or otherwise, we have every stimulus to apply our best energies to the cultivation of the soil, independently of the pleasure and satisfaction with which the study of nature is always accompanied, and the individual benefits we derive therefrom.

It may not, after what has already been stated, be deemed necessary to point out in what particular instances chemistry has benefited agriculture: but still, as some persons may not see the direct and immediate connexion that exists between these sciences, (at the risk of being considered somewhat tedious,) it is suggested, for their consideration, that the analysis of soils is peculiarly a chemical operation, and that as each individual plant requires for its perfection certain substances, the analysis of the soil in which they grow is the only way to discover if such substances are present, and if not, of indicating, what particular one is wanting, which, when discovered,

may be supplied by the knowledge chemistry gives us of other substances which may contain it.

This is, perhaps, the most important feature of chemistry as applied to agriculture, but still in its subordinate functions of enabling us to discover the elements and consequent value of refuse matters, it may be regarded as a valuable accessory to the farmer, to say nothing of its importance in pointing out remedies for such minor matters as the prevention of smut in corn, by the use of sulphate of copper—the preservation of plants by the galvanic battery—the preservation of timber by the process of kyanising, &c. all of which are of considerable value in their various applications.

To these facts may be added instances, where a knowledge of chemistry has created a new branch of trade entirely for the agriculturist, when if such knowledge had not existed, serious consequences would have ensued. The manufactures of sugar and saltpetre in France during the revolutionary war are the instances alluded to, and the circumstances which led to their introduction there are briefly these:—“That when France had lost all her colonies and when her coasts were held in a state of strict blockade by the fleets of England, the supply of sugar necessarily failed. It was then that the chemists to whom the Government applied in their emergency, pointed out that sugar might be obtained from the grape and subsequently from the beet root, and to

such an extent was this manufacture carried, that France, until a recent period (1834,) was supplied exclusively by her home manufacture."

Again, the same causes prevented France from receiving a supply of saltpetre for the manufacture of gunpowder, but the same energy which induced the home manufacture of sugar, found a means of making saltpetre from the refuse matter of farm-yards; and so great was the supply from this source that it enabled France to maintain her gigantic struggle for the subjugation of Europe, for a protracted period, with unimpaired vigour, when, had not such means been discovered, she must have submitted to what she would have considered a disgraceful peace.

Again, chemistry enables us at once to test the real value of any given substance, without the uncertainty and loss of time attendant on a trial; and when it is considered how much time must have been lost, how unsatisfactory the results must repeatedly have been, when no such knowledge existed whereby to certify the progress of discovery; the value of this science may in some measure be estimated.

Other instances might be adduced, if necessary, but enough has been said to show the intimate connexion which ought to exist between chemistry and agriculture. Indeed, the knowledge of the one is essential to success in the other; and it is hoped that the spirit of inquiry which now exists universally,

will induce the establishment of Agricultural Colleges, where young men, after having completed their education, as far as the routine and practical information necessarily connected with farming is concerned, may spend a few months in the acquisition of such chemical knowledge for the analysis of the various soils and products, as will prove beneficial to themselves as well as the community at large.

In the following pages it is intended to explain, as far as our knowledge already extends, the manner in which plants assimilate their food and the sources of its supply. To do this, some preliminary knowledge is necessary; it is therefore proposed to consider the subjects in the following order.

First—The structure and functions of the different parts of plants.

Second—The general attributes of the soil.

Third—The simple bodies forming the structure of the plant, the sources from which they are obtained, and the manner in which they are assimilated.

And lastly—The specific action of the various manures now in use.

In considering these subjects, it will be assumed that the reader has no previous knowledge of the question. No apology is therefore offered for the elementary character which each chapter will exhibit. It has been the desire of the writer to explain every circumstance as fully as possible, and although the use of technical terms is necessarily unavoidable in such a

work, still a moderate degree of attention will overcome all the difficulties, and it is hoped that the information afforded, is of that kind, that no one will regret the trifling efforts it may have cost him to overcome them.

CHAPTER II.

ON THE STRUCTURE AND FUNCTIONS OF THE DIFFERENT PARTS OF PLANTS.

THE first step, necessary to the proper comprehension of the processes nature employs in the assimilation and growth of plants is a perfect knowledge of the organs each plant possesses, and the functions these organs perform in the development of the different parts of the vegetable structure.

Without such knowledge it will be impossible to understand how plants derive their nutriment from the air and the soil, and indeed it is and must be the basis of all information on the subject.

It is proposed, therefore, to give such a general description of the functions of each organ of plants, as connected with the assimilation of their various component parts, before proceeding to the consideration of the matter so assimilated.

It is first necessary to note, that certain conditions are as necessary in the vegetable as in the animal kingdom for the development of a perfect plant.

In the latter case a due supply of fresh air,

food and liquid of some kind are the essentials necessary for the sustenance of animal life, and should but one of these be wanting, although the other two may be supplied in excess, death will ensue. So it is with plants; certain conditions are necessary to bring them to maturity, and those of each genus require a peculiar treatment to bring them to perfection; and it is the study of these peculiar conditions and the successful application of various manures to forward the development of the different organs, or the application of other substances to neutralize any quality in a peculiar soil, which would be prejudicial to the growth of a certain crop, which constitutes agricultural chemistry in its widest and most extended sense.

As a general rule, all plants consist of a root, stem, and leaves, and these organs again have a direct and distinct reference to the production of a fruit, the which being accomplished, the plant either dies entirely or lies torpid for a season, until a succession of the same circumstances which gave it life in the first instance, shall again call its productive organs into action.

The root of a plant performs the two important offices of retaining it in a fixed position and of supplying it with a great part of its nourishment, and it may therefore be considered as analogous in some measure to the mouth and limbs of an animal.

It is not at all necessary in this place to consider the different forms the root assumes in different plants, it is sufficient for our purpose

to know that the roots of all plants perform the same function, that of absorbing nutriment from the surrounding substances for the nutrition of the plant.

It may be and is matter of wonderment, that such a vast variety of shapes, should be given to an organ, provided in all cases for the same purposes; but here our inquiry must cease, an all-wise Providence has so endowed and created them, and man even with his finite understanding is capable of appreciating the benefit he derives from such an arrangement.

A root usually consists of several parts, the body, the crown or collar, the branches and the fibres, which latter seem indispensable in all plants.

The most essential part of every root is the crown, which is the portion of the plant between the stem or leaves, and the body of the root. In many plants of a hardy nature nearly the whole of the body of the root may be cut away, and yet, if the crown be uninjured, still the plant will flourish, but in the generality of plants, if the crown be injured, no matter how perfect soever the body may be, the plant is usually destroyed.

This remark applies to almost all kinds of grasses, but there are some so tenacious of life (such as the common couch-grass and plantain) that they can only be extirpated by removing every portion of the body of the root.

When the crown of a root is slender it dries up as the seeds ripen, and the plant soon dies; such plants are termed annuals, as wheat, bar-

ley, oats, &c., but when the crown, from any cause, such as the soil, climate, or culture, is rendered strong, such annuals are brought to grow two years and then are called biennials, or for a succession of years and then are called perennials.

The fibres, though an essential part of each root, may be removed in most cases without injury to the plant, provided the crown is sufficiently healthy and vigorous to push out new ones. It is at the tips of these fibres that the spongelets are placed, which absorb the pabulum from the soil, and in the event of the spongelet being removed by any cause from the point of the fibre, two lateral shoots immediately are thrown out, (provided the plant is sufficiently vigorous to bear the temporary loss it thus sustains,) each provided with its spongelet, and thus the destruction of the one becomes a source of strength to the plant. It was on this principle that Tull's famous horse-hoeing husbandry was founded: "that by ploughing between the rows of wheat, and thereby cutting off the tips of the fibres, that for every spongelet thus destroyed two were reproduced by the plant, thus giving the plant two spongelets where one had previously existed." There were other collateral benefits to be derived from this method, but the one in question was one of the principal.

That plants have the power of accommodating themselves to circumstances is proved in a most beautiful manner from the fact, that when planted in a dry and arid soil an infi-

nately greater number of fibres and spongelets are produced, than when the same plant is grown in a moist and fertile soil.

The fibres, like the leaves of trees, are produced annually, in some cases falling off like leaves, as in the Dahlia; in others increasing in size, and becoming harder like the parent body of the root, and subsequently throwing out new fibres themselves, as is the case with almost all large trees.

Besides this property of absorbing nutriment from the soil, these fibres have the power of throwing off that matter absorbed by the spongelets which is either unnecessary or noxious to the plant, and this may be one of the causes which prevents plants of any kind from being successfully cultivated on the same soil during a succession of years.

It may here appropriately be mentioned that darkness, or at all events the absence of light, is essential to the development of the fibres of the roots.

The stem is the next part to be considered, but the functions it performs in the vegetable creation are so subordinate to those performed by the root and leaves, that it will occupy but little time to become acquainted with its offices.

The stem of all plants rises immediately from the crown of the root, and is consequently always above the ground. The same variety prevails in this part of the plant as in the root, for instance: the stems of wheat, barley, and the grasses rise to some height and are termed

the straw ; the stems of mushrooms, fungi, &c. are termed the stalk, and the stem of the strawberry is termed a runner, all of them being appropriately described from the appearance each presents.

The functions performed by the stem are little more than that of conveying to the different parts of the plant the liquids absorbed by the spongelets of the root. It is somewhat porous, and evaporation of the useless moisture of the plant takes place to some extent on its surface, but compared in this respect with the leaves, its office is unimportant. It consists in all cases of cellular tissue, containing albumen, with a large portion of the earthy and alkaline matter absorbed by the roots, and it partakes largely also of the character of the plant itself in its ultimate analysis, but frequently contains a deposit of resinous or oleaginous matter, differing widely from the products of the other parts of the plant. It possesses the property of throwing out fibres and spongelets under favourable circumstances, and this mode is one of the most common means employed for the propagation of particular shrubs.

The leaves of plants are the next subject for consideration, and the important offices they perform in the nutrition of all plants will merit a careful investigation.

Nature, in all her operations, as far as human knowledge extends, is perfect. Sufficient means are always employed to obtain a given result; and hence we may justly infer that leaves from their immense number and from

the great extent of surface that they offer to the action of the air, perform a most important part in the vegetable kingdom; and it will be seen from the functions now about to be described, that their importance is not overrated.

Leaves perform, in the vegetable kingdom, the same offices as the lungs in the animal kingdom. Through them, from the pores covering their surface, the respiration of the plant is carried on, and more than this, for at the same time that the respiration is going on through their pores, a constant assimilation of one of the gases of the atmosphere (hereafter to be described) is also taking place—and from this source the plant derives a considerable portion of its nourishment; to this also we must add that a constant chemical action is always in operation in the leaves, in the formation of the resinous, and oleaginous, and acid matters they contain. These processes of the leaves are constantly in operation, from the first formation of the leaf until the seed is perfected, and they only cease when, from the ripening of the fruit, their assistance is no longer required.

It is important to remark that light is indispensably necessary to this function of plants; in its presence, both the mechanical action of evaporation of the watery parts and the secretion of the various gases is carried on vigorously; but in its absence the plant loses this power, and becomes subject in its turn to the action of the oxygen of the atmosphere.

In speaking of the root of plants it has been

noticed, that one condition essential to that part of their structure is darkness; and now it is found that light is equally necessary for the stem and leaves and other green parts of the plant. If proof were wanting to convince us of the almighty mind of the Being who has so wisely constituted this world, it might be found in the simple yet perfect arrangement now under consideration. It is a proof of the most perfect adaptation of the plant, to the conditions and circumstances necessary for its growth.

We now come to speak of the seed or fruit of plants. The object to which all the other functions of the plant are subordinate, or to which at least all parts have reference, and one which in its importance to mankind cannot be too highly appreciated.

Seeds vary in size, colour, shape, &c. to such an infinite extent as to be scarcely within the scope of human understanding; but all of them possess one uniform arrangement for the protection of the germ from injury, and it will be important to consider what this general arrangement is, and also the changes that the seed undergoes in the process of germinating.

All seeds consist of a farinaceous pulpy matter, covered on all sides by two or three membranes which serve to protect the seed from any casual injury. The pulpy matter contains at one end, the heart, or as it is more correctly termed the germ or embryo plant, and in all cases it must be remarked that the pulpy farinaceous matter is the proper food of the nas-

cent germ. Some seeds are farther protected by a hard outer covering; but this remark applies only to the seeds of trees. Although the gradations from the hard external shell of the apricot stone, to the membranous covering of the wheat are so gradual, that the line where the one begins and the other ends, is difficult to be decided on, and indeed whether inclosed in the shell or membrane, the changes all seeds undergo in the process of germinating, seems to be precisely the same, and it may be worthy of notice here, that so effectual is the membranous covering in protecting the germ from injury, that seeds found in the mummies taken from the pyramids of Egypt, which must be at least 3000 years old, have vegetated, when planted in favourable circumstances; and farther, seeds brought up from the interior of the earth in sinking wells, mines, and other excavations have also germinated, although the period when such seeds could have been deposited in such positions is altogether beyond human conception.

The circumstances necessary for the germination of the seed depend externally on heat, moisture, air, soil and situation; although these two latter conditions are not in all cases indispensable.

Moisture is absolutely necessary for the seed when planted, its first action is to swell by absorbing the pulpy matter of the pod, which then bursts open and allows the air to act in concert with the water thus absorbed, in creating new compounds, such as starch, sugar,

resin, &c. which form the pabulum or nourishment necessary for the young plant in its first stage of existence, and before its organs are sufficiently developed to obtain a supply of food elsewhere.

Heat follows next, and is equally indispensable to the germination of the seed. A temperature below 32° or much above 120° are the extremes, beyond which vegetation does not take place; in the one case from the freezing or extreme cold, closing the pores of the seed to the moisture, and in the latter from the extreme heat, causing the fluids of the seeds to be too much expanded, when decomposition of the parts takes place.

Air is also an essential ingredient in the germination of seeds, from the presence of its oxygen. And it is probable, to the absence of this cause, that seeds found buried in the earth, under what would otherwise be considered favourable circumstances for their growth, have lain so long dormant.

Light, so necessary to the favourable growth of the plant itself, is prejudicial to the development of the germ, from its power of disengaging the oxygen necessary to the vitality of the embryo of the plant.

Soil and situation need not here be discussed, as these attributes will be considered more at large in the ensuing chapters.

Electricity is also presumed to have an important effect in causing the germ to vegetate and assume the functions of an organized plant, but as yet this is only a surmise. The know-

ledge of this omnipresent agent is yet too limited to say if such is the case, and if so, to say how it operates, but that it does extend and exert its influence on such objects is almost beyond a doubt.

CHAPTER III.

ON SOILS.

To enter fully into this branch of the subject, and with all the detail which its importance deserves, would require a volume of itself, and would far exceed either the limits or the intention of this elementary work.

It must suffice here that a general outline of the characteristics of the soil is given; that the source from which its fertilizing properties are derived, is pointed out; and that attention is called to the benefit to be always derived from a judicious admixture of the various kinds of soils. This, with a few remarks on the necessity that exists for a rotation of crops, and the benefit that arises from allowing the land either to lie fallow or at least to be cropped only with such crops as do not exhaust the soil, and which from this circumstance are termed fallow crops, will comprise all the information it is proposed to bestow on this subject.

Soils are distinguished by a variety of names, according as a particular substance predominates in them. Thus calcareous soils are those containing lime in greater quantity than any other ingredient.

Argillaceous soils are recognised from the clay and the oxides of iron, which predominate in them.

Peaty soils are those where decayed vegetable matter exists to the exclusion of almost all other matter, and all other soils are equally recognised and distinguished from the character of the predominant ingredient.

Sir Humphrey Davy, in his profound work on Agricultural Chemistry, when speaking of soils, says "That for all useful purposes, the various soils are sufficiently recognised, and that any attempt to class them with scientific accuracy, would be a vain labour, the only thing necessary being a clear comprehension of the terms made use of."

But in quoting this passage it must be distinctly stated, that this opinion does not militate against that previously expressed, in which a correct analysis of the component parts of the soil is considered to be of the first importance, and one on which the value of agricultural chemistry mainly depends. It is merely intended to state that to attempt a description with scientific accuracy of the various soils would be a hopeless task, without at all detracting from the value of a correct analysis in every position where it is possible.

It is therefore assumed that the recognised distinctions already existing are sufficient for the purposes of agriculture, and the consideration of the functions performed by the soil and the fertilizing properties it contains is at once proceeded with.

Soil is the general name applied to the surface of all sorts of land. It consists of the fine powdery material formed by the chemical and mechanical action of the air, water, and different degrees of temperature, from the primitive rocks of the earth, incorporated with each other in an endless variety of proportions, and mixed with decayed and other vegetable matter in every stage of decomposition.

The soil thus formed affords a place for vegetable life, by enabling the seed and plant there to fix itself mechanically to one spot, and by its peculiar properties of affording moisture and the other ingredients necessary for the development of plants in all their stages, to arrive at maturity and thus furnish a supply of food to man and animals.

The various ingredients necessary for vegetable life all exist in the primitive rocks of the earth, and by their destruction these ingredients are rendered available for plants, and as farther this disintegration is constantly going on, it must as a matter of necessity arrive that a greater power daily exists for the support of the vegetable creation.

The substances produced by the decomposition of the various strata of the original rock are potash, soda, phosphoric acid, magnesia, lime, and silex. Hereafter, in the consideration of these various substances, their specific mode of action on plants, and the immediate sources of their supply, will be described—here they are only noticed as being set free by the disintegration of the original rock of the earth.

That such disintegration is constantly going on, is evident from many causes—and one which is, perhaps, the most convincing of any is, that the lavas in Sicily, which have been thrown out from Mount Etna within a comparatively recent period, are now found covered with a fertile soil, which could only have arisen from this source—and which is proved to be derived from this cause by the chemical analysis of the rock itself, which yields the substances found under other modifications in the soil itself.

This fertility is owing to the alkalis which are contained in the lava, and which, by exposure to the combined action of the air and moisture, are reduced to a state capable of being absorbed by plants.

A soil which has been subjected to this influence for ages, and from which no crops have been removed, will be enabled to support a luxuriant vegetation for many seasons successively, without any supply of manure, simply because the soil is full of the alkaline matter, phosphates, and other ingredients necessary for the growth of plants; but when under cultivation and when the crops are removed from it, it must become gradually exhausted, and unless the alkaline property removed with the crop is restored in the shape of manure to the land, the soil will be eventually quite unable to support a crop and bring it to perfection. But if when such exhaustion of the land has occurred the soil is allowed to lie fallow or cropped only with such plants as do not require

such alkaline matter for their nourishment, the soil will, by the continuous action of the air, &c., in effecting the decomposition of the primitive rocks, again acquire a supply of those alkaline salts to be enabled to perfect a crop.

The plants which may be termed strictly fallow crops are beans, peas, and buckwheat, as the ashes of these vegetables when analyzed scarcely yield a trace of the alkaline salts, or phosphates; next to these may be classed turnips, cabbage, beet and potatoes, which exhaust the soil more than the preceding, but still not to the extent that the white crops, such as oats, barley and wheat, which require such a supply of the alkalis and phosphates for perfecting a crop as usually to exhaust the soil in one season.

A peculiar case of the rotation of crops occurs at Manningford, and other places in the neighbourhood of Pewsey in Wiltshire. There the invariable rotation is wheat and beans, and has been so for fifty years past, experience having taught the agriculturist there, that that system is the best, and a knowledge of chemistry explains how it is, that it is so.

Wheat absorbs the native phosphate and alkaline salts, leaving the soil, we will suppose, for the sake of argument, quite exhausted of these necessary ingredients, and leaving of course the excrement which all plants exude from the roots during their growth. The succeeding crop beans, does not require for its perfection either phosphates or alkaline salts, simply a supply of carbon, and therefore as far as

the wheat is concerned, the earth is, by the disintegration of the original matter of the soil, again acquiring a supply of those salts and phosphates, during the growth of the beans; and this, with the manure which is applied, is sufficient to furnish a supply for the wheat in the succeeding season. In addition to this the excrement of the one may furnish the pabulum for the other, and thus each has a beneficial effect on the succeeding crop.

Experience also has taught us, that beans alone are not a sufficient food for horses. It is customary always either to mix chaff, or generally bran with the beans, to supply the necessary amount of phosphates required by the horse for supplying the waste of the body; and thus chemistry explains and confirms the policy of this mode of treatment which long experience only has taught.

Decaying animal and vegetable matters is also another and a very fertile source of the supply of nutriment to plants—and all soils contain more or less of this matter in some state or other—but the consideration of the immediate effects produced on vegetation by these substances, is likewise postponed until its effects are explained in a succeeding chapter; their presence is only noted here as forming one of the principal constituents of the soil.

From the remarks we have already made, it will be evident that no plants which require the same substances for their support can be successfully cultivated, either together or in

succession, because the soil requires time to recover itself, or to reproduce a supply of the various substances necessary for their perfection : but in addition to this cause there is another, which, under the rotation of crops, is indispensable in a judicious system of agriculture.

From experiments that have been made by Decandolle and others, and repeated by Leibig, it is established beyond all question that the roots of plants throw off an excrement during the progress of their growth, and that the excrement of each plant is peculiar to itself. And farther, that the presence of such matter in a soil, impedes the growth of plants of the same kind, whilst in some instances it becomes a source of nourishment to others.

This fact is another argument in favour of the necessity of a rotation of crops. And much will depend upon the nature and character of the soil itself as to what time should elapse before a certain crop may be successfully repeated.

If the land is light and porous this excrementitious matter will in all probability be so decomposed by the combined action of the air and moisture, as to be entirely dissipated in the course of one or two seasons; but if, on the contrary, the soil is of a stiff retentive character, four, five, and even six years may elapse before this matter shall be so destroyed as to allow a repetition of the first crop.

It may be argued against this theory, that many crops, such as Lucerne, for instance,

grow for many years successively in the same spot; but a careful attention even to this crop will convince even the most skeptical of the universality of this law. If, for instance, a field of Lucerne is planted, and no manure of any kind is applied, it will be found after a few years to have lost much of its fertility, and that the produce is lessened considerably in amount; but that, after being in this state for some time, perhaps a year or two, the plant seems to recover itself, and even an increased vegetation takes place.

This is to be accounted for thus—the plant during the first year of its growth throws off a quantity of excrement, which increasing year by year in the soil faster than it is decomposed by the air, at last is so prevalent, that the plant can obtain scarcely any nutriment from the soil, and consequently is enfeebled in its growth, and throws off comparatively no excrementitious matter to the soil. When this state of affairs has arrived, the action of the air on this matter gains on it, and in the course of one or two seasons the whole of it is so reduced as to act as a stimulus to the plant itself, and give it apparently a new life, by supplying it with a quantity of carbon for its assimilation.

This decomposition may however be otherwise affected by constantly turning the land, and by adding small proportions of quick lime, which would hasten the process of decay, and thus prevent the barrenness of the plant from taking place.

Thus the rotation of the crops is necessary

from two causes: the first, that each plant or crop takes away from the soil the matter suited to itself and thereby exhausts it; the other, that it leaves an excrement behind which acts as a poison to plants of the same kind; but which excrement in some instances serves as the nutriment of other plants, and in all cases may be destroyed by exposing it to the action of the air, or by mixing with it such manures as will readily effect its decomposition.

After what has been already said on the exhaustion of soils by a particular crop, it will be hardly necessary for us to point out the advantages that may be derived from a judicious admixture of various soils, in which the deficiencies of the one may be supplied by the excess of the others. Indeed it is on this principle, that of supplying a soil with the ingredients necessary for the support of plants, and neutralizing other substances, which may be prejudicial to them, that the whole merit of agricultural chemistry belongs, and much may be done in this way, in every situation however destitute; and at the present time when the facilities for transporting matter of all kinds, by means of railroads, are taken into consideration, it may not be an unreasonable expectation to hope to see eventually the barren hills of one district, manured and covered with the alluvial deposits of others, in a high state of cultivation; and then the benefits which science has conferred on the community at large, and which in this instance serves in some degree to annihilate space, and to equalize

the blessings which Providence has so bountifully placed at the disposal of its creatures, may in some measure be appreciated.

There are many other branches into which this subject would lead us, had we the intention to pursue it; for instance, the character of the sub-soil, whether chalk, gravel, clay, or stone, are all matters of paramount importance to the agriculturist. The colour also of a soil, and its capabilities thereby of absorbing and retaining the rays of the sun, is another circumstance, to which perhaps too little attention is paid; again, its local position, whether it lies open to the genial south, or is exposed to the north, should be, and is a matter of importance in determining the crops, and the seasons for sowing them; and another feature is the quality of the water which exists in the neighbourhood, and its influences, as well on the meadows which it irrigates, as on the cattle and stock of the farm.

All these are subjects of inquiry and of importance, which require a careful consideration in adapting the crops, best suited to the capacity of the soil to perfect them, and we may feel assured that those persons who pay the greatest attention to these minutiae will be amply rewarded, in the increased produce of their farms, or certainly in not being disappointed in the results they may have anticipated.

CHAPTER IV.

ON THE ASSIMILATION OF MATTER BY PLANTS.

THE consideration of the phenomena to which this subject will give rise, extends over a wide field of inquiry, and will embrace the consideration of every substance, which in any way either forms a part of the vegetable structure itself, or which serves as a means of conveying or affording such matter to plants.

In pursuing this subject, many facts may be communicated to those whose attention has not been turned to this inquiry, which may seem almost beyond the range of credibility; but as nothing will be stated which cannot be vouched for, on the testimony of the first authorities on such subjects, the most complete reliance may be placed on the information it affords; and if, in the discussion to which this article may give rise, the attention of other parties, better qualified, both by their abilities and the opportunities which they may have of verifying the results, is called to this subject much good will ensue. Truth will be elicited, and society must thereby derive a substantial benefit.

In the chapter on the structure of plants, it has been stated that the spongelets of the roots

and the leaves, are the only means by which plants can derive their supply of food.

The spongelets of the roots, taking up the liquid matter which is found in the soil, and the leaves absorbing the various gases, which serve as a pabulum for the plant, from the air.

Thus plants, in contradistinction to the animal tribes which exist on a mixture of solid and liquid food, exist entirely on liquids, as nothing can be absorbed by the root which is not in a fluid state, and the gases taken up by the leaves are equally fluids in a much more subtle state of division.

From the most careful and recent chemical analysis of the matter, forming the structure of plants, it appears that all the various substances which enter into the composition of the vegetable tribe are reducible into the four following simple gases, viz.

Carbon,
Nitrogen,
Hydrogen,
Oxygen;

and that these gases, combined in different proportions, and mixed with such earthy matters as potash, soda, lime, phosphorus, and magnesia, are the simple substances from which all vegetable products are elaborated.

To give, therefore, such an account of the means employed for this purpose, as shall carry conviction on the subject, it is proposed to consider each body separately,—defining

the source from which it is derived, the state in which it exists in nature, its character and general attributes.

In pursuing this plan each subject will as much as possible be confined to its own limits, but in some cases this will be impossible, as the substances about to be considered are so intimately blended the one with the other, as to render a description of the one necessary to the elucidation of the other.

One substance, which, although a compound body composed of two gases, is yet, in its compound state of *water*, so important an element in the economy of plants, that the changes it undergoes and the functions it performs will be considered when speaking of hydrogen, with which it is so intimately connected, as to be incapable of separation.

OF CARBON.

Carbon, the first and prime necessary of vegetable life, exists abundantly in nature in three or four states. First, it is a component part of the atmosphere surrounding the globe, one thousand parts of which contain three parts of this gas. In this state it is known as carbonic acid gas, that is carbon united with oxygen gas, and it is one of the most universally diffused substances in nature. It exists in another state, as charcoal, which is almost pure carbon, and lastly, in the diamond, which is pure carbon in its crystalline state.

The difficulty here arises how to prove that substances so dissimilar as carbon in the gaseous state, charcoal, and the diamond, are one and the same substance. To detail the history of all the researches which have justified the first chemists in arriving at such a conclusion, would be to far exceed the limits of this work; this fact must be admitted, and the proof that such may be the case, must be demonstrated by an appeal to a substance which is more familiar, and which in its three states of solid, liquid, and aëriform is quite as dissimilar in its appearance as the diamond, charcoal, and carbon.

Water exists in three states, according to the temperature in which it is placed. It exists as steam at a high temperature, as water at a medium, and as ice at a low temperature; and yet who, who had not cognizance that such is the case, could have believed that ice and water were merely modifications of the same substance, or that steam was only water in a different state? So it is with carbon; an increase of temperature causes the diamond itself to burn and resolve itself into an aëriform state. Charcoal does the same; the only difference is, that we cannot reproduce these substances from the gaseous state, with the same facility that we can reduce steam to water, but still this is no argument against the proposition that charcoal, carbon and the diamond are the same substances, produced or existing under a different form;

it is merely an admission of our ignorance in not knowing what circumstances are necessary for their production, or in not being enabled as yet so to arrange such circumstances, so as to produce them.

In its gaseous state, as carbonic acid gas, carbon is invisible, and has a sour sharp smell and taste. It is destructive of all animal life, not so much apparently from any noxious quality it possesses as from the absence of a due quantity of oxygen to support the vital functions. It is constantly met with in old wells, brewers' casks, &c. and may be produced at pleasure by mixing a small quantity of whiting or marble with strong vinegar or dilute sulphuric acid, when an effervescence immediately takes place, and the gas so liberated, is tolerably pure carbonic acid gas.

The results of the ultimate analysis of various vegetable substances is here given, that it may be seen how important a part in the vegetable economy carbon performs, and that the importance attached to it, in this work, is not overrated; and it must be here impressed forcibly on the reader, that no substance whatever can be produced in plants unless the elements composing it are present, and that although plants possess the power of decomposing one substance, and combining one of its component parts with another substance, or in different proportions with the same matter it was previously combined with, and thereby producing a new compound differing materially

from its original state ; still that they have not the power of creating new matter, and that all the products of plants are derived from the absorption of their component parts, from the atmosphere, or by the roots, or from the decomposition of other matter in the structure of the plant itself. This fact cannot be too much impressed on the mind, and all the subsequent reasoning herein contained will depend upon this acknowledged truth.

The ultimate analysis of sugar, a vegetable product of the most useful kind, in its influence on the comforts and luxuries of life, as widely diffused in the vegetable world as it is useful, consists of,

Carbon 43 parts,*

Water 57 parts.

The better the sugar the larger the quantity of carbon. Hence the trade distinction of high and low sugars, the former containing a large quantity of saccharine matter, and being in every respect a better article than the latter.

The analysis of starch, another vegetable product almost equally diffused, consists of

Carbon 38 parts,*

Water 62 parts.

The analysis of gum which exists in the farina of all seeds, and frequently exudes from the bark of trees which have received any injury, consists of

Carbon 36 parts,*

Water 64 parts.

* Henry.

Woody fibre contains 38 per cent of carbon, Meadow hay contains 44 per cent of carbon.*

The analysis of vegetable oils, such as olive or linseed oil yields carbon 77 parts.

In all these analyses water is stated instead of its component parts of oxygen and hydrogen, this is done to simplify the subject under consideration; but the analysis of water will be considered in its due and proper place.

From these results it must be apparent that a due supply of carbon is absolutely necessary to vegetable life, and to enable plants to create such substances as sugar, starch, mucilage and oils. From whence that supply is obtained will now form the next subject for our consideration.

“Vegetable physiologists have hitherto considered the fertility of every soil to depend on the presence of a substance called humus. This substance, hitherto recognised as the nutriment of plants and believed to be extracted by them from the soil in which they grow, is itself the product of the decay of other plants.”

“It has been called by a variety of names, such as humus, humic acid, coal of humus, &c. according to the external characters each species has presented, and hitherto the opinion, that this substance humus is united in some way or other with the carbon, has been so prevalent as to seem to require no argument in its favour.”

“The obvious difference in the growth of plants, according as the soil contained a greater

* Liebig.

or lesser quantity of this substance, seemed to afford incontestable proof of its correctness."*

Yet this position is found to be untenable, and conclusive proofs will be offered to show that humus of itself does not enter into the composition of any plant, or afford them the smallest nourishment.

It has been already noticed, in considering the structure and functions of vegetables, that the roots, the only source by which humus or humic acid could be introduced into plants, can only absorb nourishment in the shape of a liquid, and if it can be proved that the substance now under consideration, humus, is insoluble in water, it must be at once admitted that it cannot perform the office hitherto ascribed to it, and that search must be made elsewhere for the pabulum of plants.

It has been demonstrated by Sprugel, a German chemist, that humic acid is only soluble in 2500 times its weight of water, and even to possess this degree of solubility it must be acted on by the water as soon as it is formed from the humus, and that it forms compounds with potash, soda, lime and magnesia, but none of which possess a greater degree of solubility than the humus itself. And it has been farther demonstrated that if by any chance it should become dry by exposure to the atmosphere, or be subjected to a temperature lower than 32°

* Almost all the arguments in favour of the theory here promulgated are taken from Professor Liebig's work before noticed, and in some cases the exact words of the translation are quoted.

that it becomes and remains perfectly insoluble in water under any circumstances.

These facts, which demonstrate plainly that humus, or humic acid, cannot enter into the composition of plants, have not been overlooked by vegetable physiologists; but they have supposed, that, under certain circumstances, the alkaline earths might act upon the humus, and render it soluble, and thus in a fit state for the assimilation of plants; but by calculations made by the author of the work before quoted,* it is proved beyond all question, that even supposing humus in its most soluble compound, that is as a humate of lime, to be absorbed by plants, still that the produce of a given field so far exceeds the quantity of humate of lime, that could by any possibility either exist or be created on such a field, under the most favourable circumstances, that some other cause must be assigned for the source of nutrition to plants.

Another argument that is conclusive on the subject of humus not forming the nutrition of plants is, that as humus is the result of the *decay* of vegetable matter, from whence did the first vegetables derive their supply of this supposed necessary substance?

We have seen in the analysis of hay that 100 parts consist of 44 parts carbon. Hence the produce of an acre, weighing one ton must contain about 985 pounds of carbon. An acre of wheat also, yielding eight sacks, and weighing 2000lbs., must produce about 600lbs. of

* Sprugel.

carbon, exclusive of that contained in the straw and roots. Again we have seen that woody fibre contains 38 per cent. of carbon, and wood in its growth continues to assimilate this quantity annually for a long series of years, in the production of timber. The question therefore that now arises is, from whence do these organic substances derive their supply of this article? In the case of the hay and the wheat-field, it may be argued that the manure applied to the land furnishes this supply; but then, it may be asked, whence does the water meadow, and the forest derive this supply, seeing that in neither case is any manure applied for many years together, and yet the produce of vegetable matter is equally great.

It is not intended by this argument to deny the benefit that manures do to the soil, and it will be seen in the sequel, the importance attached to them. But here the question is from whence is the supply of carbon obtained? and it may be positively affirmed, that the manure applied in any case to the land, does not afford a sufficient quantity of this substance to account for the immense quantity existing in the produce of the land. The answer to this question embraces a considerable field of inquiry, and one which when fully considered, will open our minds to the great and wonderful powers of nature, in the means employed for equalizing matter, and restoring and keeping up the harmony that should and does exist in all parts of the vast scheme of the creation, and one which cannot fail to impress us with the

omnipotence of that Almighty being, who, for purposes far beyond our finite comprehensions, has placed man at the head of this scheme, indued with power to use these influences for his own good, and with necessities which compel their action.

It has previously been stated, that carbon exists as a gas in the atmosphere which surrounds the globe, and although its quantity may appear too limited to produce the effects attributed to it, still when the immense extent of the atmosphere which surrounds the globe is taken into consideration, and the constant supply of carbon which is furnished by mankind and all animals in the process of respiration, and the quantity that is yielded in the process of combustion, our wonder will cease, and will be directed to that principle of vegetable life which can absorb such a vast amount of noxious matter.

In addition to the carbon, 100 parts of the atmosphere which surrounds the globe, consists (in every climate, and in every situation) of 21 parts of oxygen gas, and 79 parts of nitrogen. Here we have only to speak of oxygen, and the consideration of nitrogen and its effects on vegetation, must be postponed to a succeeding chapter.

Oxygen is the great supporter of animal life during the process of respiration. In this process the atmospheric air is taken into the lungs, and one portion of the oxygen it contains is absorbed by the blood, and another unites with the carbon of the blood brought up by the

veins in their return to the heart from different parts of the body, and is exhaled in the state of carbonic acid gas; and this gas so exhaled, is, of course, unfit for respiration until the carbon it contains is absorbed in some way or other from the oxygen.

Now it is calculated* that a man consumes every day, in the usual course of respiration, 45,000 cubic inches of oxygen gas; that a thousand millions of men consume in one year $\frac{1}{1000}$ of all the oxygen that exists in the atmosphere: and hence, in the course of time, all this gas, the prime necessary of life, would be entirely consumed, if some corrective power did not exist to neutralize this effect. For this power we must look to plants. It has been explained that the gas exhaled from the lungs of all animals is carbonic acid gas—that is, carbon combined with oxygen—and we are now in a position to prove that plants absorb all this carbonic acid gas. That they assimilate the carbon to themselves, and give up the oxygen in a pure state again to support animal life, and again to enter into the state of carbonic acid, and again to be purified in the vegetable structure, and thus to perform its office in an unceasing round of useful operations.

In the calculations here submitted, all notice of the quantity of carbon emitted by animals, or in the process of combustion is omitted—and yet these sources supply a quantity of carbon considerably greater than those we have

* Liebig.

instanced: however, it is enough for the purpose proposed, and it only remains to prove that the purification of such effluvia is the office performed by plants.

This peculiar property of the vegetable tribe is so easy of demonstration that every one may convince himself of its existence with very little trouble.

The leaves and green parts of plants absorb carbonic acid gas, and give off an equal volume of oxygen, and this they do quite independently of the plant itself. For instance, if the stem of a plant is placed in water containing carbonic acid gas, and in this state exposed to the sun's rays, the carbonic acid is found to have entirely disappeared from the water, and if the experiment has been conducted under a glass receiver filled with water, an equal bulk of oxygen gas will be found to have been emitted, and when no more gas is given off, it is a sign that all the carbonic acid gas is decomposed, but the process immediately recommences if a new portion of it is added.

The experiments of De Saussure farther prove that plants increase in weight during this decomposition, but in a greater proportion than can be accounted for by the assimilation of carbon alone; and hence it is referred that hydrogen, one of the elements of water, is assimilated at the same time, and thus a new source of oxygen arises to supply the loss the air is constantly suffering.

This simple experiment incontestably proves that carbon is assimilated by the leaves of

plants and explains the means nature employs for purifying the atmosphere of such an amount of noxious matter. The proofs might here be multiplied that such is the case, but the one stated is so easy of comprehension, and so readily exhibited, that it is useless to do so.

It will be explained farther that the roots also absorb a portion of carbon, which is equally assimilated by the plant, and thus perform their part in this attribute of the vegetable tribe, but as the carbon so absorbed must be dissolved in water, its consideration will be considered under that head.

Another source of carbon to plants arises from vegetable matter in a state of decay. Decay is only another word in chemistry, for the slow process of combustion, where in the plants are acted on by the oxygen of the atmosphere, and give off the carbon they had assimilated during life, in union with a portion of the oxygen in the state indeed of carbonic acid.

All decaying vegetable matter under favourable circumstances as to moisture, temperature, &c. is surrounded by an atmosphere of this carbonic acid gas, formed at the expense of the oxygen of the atmosphere, and as this process is carried on equally well in a soil permeable to the air, as in the air itself, it is a continued source of carbonic acid gas, which it emits very slowly, and which is thus enabled to be absorbed by plants growing near it.

In the early stages of vegetable life, before any leaves are formed, and when consequently

the plant possesses no organs for absorbing the carbonic acid from the atmosphere, the substance of the seed itself, as before stated, furnishes the necessary pabulum for the formation of the root, which once formed immediately performs the functions of the leaves as well as root, by absorbing the carbonic acid gas given off by the surrounding decaying vegetable matter, as well as moisture, and the other ingredients of the soil; and as the leaves and other parts of the plant are developed, nutrition is derived by the plant both from the roots and the organs above the ground, and in this stage it advances rapidly to maturity, but when the plant is quite matured and the organs by which it derives its supply of food from the atmosphere are quite perfected, the carbonic acid gas of the soil is no longer required. Deficiency of moisture does not now arrest the progress of the plant, provided it is enabled to derive from the atmosphere and dews sufficient for the purposes of assimilation, and carbon during the heats of summer is derived exclusively from the atmosphere.

When the supply of food to a plant is greater than it requires for the development of its organs already existing, the superfluous nutriment is not returned to the soil, but is employed by the plant in the formation of new organs and in increased luxuriance. At the side of a cell already formed, a new cell arises, at the side of a branch and leaf a new branch and leaf are developed, and these new formations owe their existence entirely to an excess

of nourishment. The power of absorbing nutriment therefore from the atmosphere, with which the leaves of plants are endowed, being proportionate to the extent of this surface, every increase in the size and number of those parts is necessarily attended with an increase of power, and, in consequence, to a certain extent, farther development of new leaves and branches.

This process is continually in operation ; it commences with the first formation of the leaf and does not cease with its perfect development ; but the matters derived from the continued assimilation by the perfect leaves are no longer employed in their own increase, they now serve for the formation of woody fibre, sugar, starch, &c. in the ripening of the fruit, when the functions of the leaves of most plants cease, because the products of their action are no longer required, and they then yield to the action of the atmosphere, change their colour and fall off, or, as in annuals, they partake of the general decay of the whole plant.

A vast deal of controversy has taken place, on the subject of the absorption of carbonic acid gas by plants, by authors of considerable ability on both sides ; but the details here introduced, are, it is imagined, sufficient to prove, both by direct and collateral arguments, that the view now taken is correct, and it is generally admitted to be so by the most eminent physiologists of the present day. It will be desirable however to continue the subject farther, and detail some of the experiments made

with a view to prove that carbon did not form the pabulum of plants. The circumstances also under which plants yield carbon to the atmosphere instead of absorbing it, must be explained, and in doing so, a very nice, but at the same time a perfectly clear and lucid distinction between the chemical transformations and mechanical operations carried on by plants will have to be considered.

With a view to determine whether carbon actually formed the principal nutrition of vegetable life, seeds have been planted in fine marble reduced to powder, and in flowers of sulphur, and watered with water containing carbonic acid gas in solution. Under these circumstances, the seeds have generated and lived to produce two or three leaves, but never more, and in all cases the plant has then died: and such experiments as these have been adduced as conclusive evidence that carbon does not form the nutriment of plants; but the parties making these experiments have either been willingly or culpably negligent in arriving at this conclusion from such data.

It will be seen as we proceed that many conditions are necessary for the life and development of the organs of plants, and that it is not enough that one element forming it is admitted, the principal nutriment should be present, but the combined action of all is necessary.

The organs of plants as well as of animals, consist of a variety of substances, some requiring carbon, others nitrogen, others again hydrogen, and all the presence of metallic ox-

ides and earthy salts, for their perfection. Is it to be expected, therefore, that when only one of these necessities is present, that a healthy and vigorous plant is to be the result, or that because such plants did not succeed, that the element spoken of forms no part in the vegetable economy? Certainly not, and the manner in which these experiments were conducted is opposed to all the rules of philosophical inquiry, and to all the laws of modern chemistry.

The other objection which has been taken to the assimilation of carbon by plants has arisen from the fact, that under certain circumstances plants give off carbonic acid gas instead of assimilating it. In the chapter on the functions of plants it has been explained that light is an essential to the process of the assimilation of carbon, and that the decomposition of carbonic acid is arrested by darkness. But then, namely at night, a true chemical action of the oxygen of the atmosphere commences on the leaves and other parts of the plant. This process is not at all connected with the life of the plant, as it acts in a similar way on the dead plant; indeed, this result must not be considered in any way as the act of the plant itself, but as the effect of the oxygen of the atmosphere acting on the plant at a time when its own powers of assimilation are in abeyance; and yet, notwithstanding these adverse circumstances, it will be demonstrated still that plants absorb more carbon during the day than is given off by them during the night, and that in regarding them as the great purifiers of the at-

mosphere of the carbon exhaled by all animals, their proper attribute is only assigned to them.

A soil in which plants vegetate vigorously contains moisture, which is indispensably necessary to their existence. Carbonic acid also is always present in such a soil, whether it has been abstracted from the air, or generated by the decay (as before explained) of vegetable matter, and water also, from whatever source in nature it is derived, invariably contains carbonic acid gas.

Plants during their life possess the power of absorbing, by the spongelets of the roots, moisture, and this moisture contains carbonic acid gas, derived from either of the sources above described. Is it therefore surprising that plants should again give off this carbonic acid, when light, the power which enabled the plant to decompose and assimilate this carbon, is absent?

Carbonic acid thus absorbed by the roots is dissolved in the sap which pervades all parts of the plant, and evaporates every moment through the leaves with the water, in quantity corresponding to such evaporation.

“Neither this emission of carbonic acid nor the absorption of oxygen has any connexion with the process of assimilation. The former is a mechanical, the latter purely a chemical process.” If this view of the subject is correct, those plants which require the presence of oxygen to convert their volatile constituents into resins, should absorb the most when the influence of the light is withdrawn, and such

we find to be the case, for while the tasteless leaves of the American aloe absorb only 0.3 of their bulk of oxygen during the dark, the leaves of some of the fir tribe which contain volatile and resinous oils absorb ten times and the leaves of the oak containing tannic acid, fourteen times that quantity.

This chemical action is shown also very plainly in the leaves of the *Cacalia ficoides* and others, which are sour in the morning from the absorption of oxygen during the night, tasteless at noon from the assimilation of carbon during the sun's light, and bitter in the evening, when in addition to the carbon a portion of the hydrogen of the water, a component part of all bitter substances, has been assimilated.

Indeed the quantity of oxygen absorbed can be estimated pretty nearly by the length of time which the green leaves of plants require to undergo an alteration in colour, by the influence of the atmosphere. Those which continue longest green will abstract less oxygen from the air, than those which change colour more rapidly.

Thus the leaves of the beech and poplar absorb eight or nine times their bulk of oxygen in the same time that others, whose durability as to colour is greater, absorb only two or three times that quantity, and when these leaves are dried, in the dark, in the vacuum of an air pump, moistened with water and placed in a vessel filled with oxygen, they are found to change colour exactly in the proportion in

which the gas is absorbed. The chemical nature of this process is thus completely established.

There are other facts which prove in a decisive manner that plants yield more oxygen to the atmosphere than they consume, but these proofs must be drawn from those plants which live under water.

“When pools and ditches, the bottoms of which are covered with plants, freeze on their surface in winter, so that the water is completely excluded from the air by a stratum of ice, small bubbles of gas are observed to escape continually during the day from the points of the leaves and twigs. These bubbles are seen most distinctly during the day when the sun’s rays fall on the ice, they are very small at first, but eventually form large bubbles. These consist of pure oxygen gas, and neither during the night nor during the day even, when the sun does not shine, are they observed to diminish in quantity. The source of this oxygen is the decomposition of the carbonic acid gas by the plant, the carbon of which is assimilated, and the oxygen evolved, and the water is again supplied with carbonic acid by the continuous decay of vegetable substances contained in the soil.”

The principal sources of carbon, and the manner in which it is assimilated by plants in the beautiful system of nature have now been considered, and yet many questions may arise respecting it; one of the most obvious is, that if plants are intended by nature to perform the

functions here described and to be the purifiers of the atmosphere, how can it be explained that a larger proportion of carbonic acid does not exist in the atmosphere during the winter, when vegetation is completely torpid, than in the summer; seeing that in the one case every source for the supply of carbon exists in excess, and in the other that all the sources for the supply of oxygen are in abeyance?

“This would certainly form a cogent argument did we not look on the whole field of creation at once. The proper, constant, and inexhaustible sources of oxygen gas are the tropics and warm climates; where a sky, seldom clouded, permits the sun to shine upon an immeasurably luxuriant vegetation. The temperate and cold zones must on the contrary produce a superabundance of carbonic acid, which serves as a supply to the tropical plants, and the same current of air which in its constant passage from the equator to the poles, brings with it a supply of oxygen, also takes away the excess of carbon, and thus equalizes the blessings of a pure air to the whole earth.”

Thus plants not only afford the means of nutrition to all animals, but they likewise perform an important part in the creation in purifying the atmosphere from all noxious matter, and furnishing an inexhaustible source of pure oxygen.

Animals, on the contrary, consume the oxygen and expire the carbon, which furnishes

nutrition to plants ; and thus the medium in which both exist, namely, the atmosphere, is maintained constantly unchanged.

“ The presence of a rich and luxuriant vegetation may be conceived without the presence of animal life. But the existence of animal life, constituted as we now are, is undoubtedly dependant on vegetable life for its support ;” but both are interwoven in such a manner as to call forth our highest expression of admiration of the system, and devotional feelings of gratitude to the Being who has so constituted this scheme, and who has given to man the power in some measure to comprehend its perfections.

ON NITROGEN.

Nitrogen, the next in order and in necessity for the development of plants, is only known in its gaseous state, or in combination with other gases in a fluid or solid state, as in nitric acid and salammoniac, or combined with salts in a solid form, such as nitrate of potash, &c.

Nitrogen also forms the great bulk of the atmosphere surrounding the earth, 100 parts containing 79 parts nitrogen, and 21 oxygen ; and it is remarkable, that although these gases possess very different specific gravities, that the atmosphere under all circumstances is composed of exactly these proportions,

united with the portion of carbon before noticed, but which need not here be farther discussed.

It appears to possess of itself a negative effect on the animal frame; its only use being apparently to dilute the oxygen: but in the vegetable economy its functions are far more important, as it enters into combination with many other substances composing the structure, and is itself assimilated, and constitutes the most nutritious part of plants.

It differs, however, materially from carbon, the subject of the last section, in this respect, that it is never absorbed by the leaves, or the green parts of plants; its only access is by the roots in a fluid state: and this, therefore, will simplify materially the consideration of this substance.

It is to the presence of this gas, assimilated and combined, in the farina of wheat, oats, barley, &c., as well as in the flesh of animals, that the nutritive qualities of these substances are to be attributed, and in proportion as this gaseous body is present in each case so is the nourishment the food contains.

The form in which nitrogen generally presents itself to our senses is in combination with hydrogen, (one volume of the former combining with three volumes of the latter) and in this state it is known as ammonia; this substance again combines with carbonic acid gas, and forms carbonate of ammonia, one of the most universally diffused substances in

nature, and one, as this article will demonstrate, of the most vital importance in the economy of animal and vegetable life. The process by which vegetables have the power of forming this compound, and the sources from which it is obtained, will now form the subject for our consideration.

The portion of farinaceous matter in which the nutriment resides, is what is termed the gluten, and it may be easily prepared from wheat flour, by mixing it into a paste, and washing it constantly with water until the water runs away quite transparent. The pure gluten then remains, and when dried, it somewhat resembles glue, and is in every respect perfectly analogous to animal gluten.

This substance has never yet been analyzed with a view to obtain its ultimate constituents; but Dr. Henry, in speaking of it, says, "It closely resembles animal gluten, especially in the large quantity of nitrogen which enters into its composition." It may here be stated that the value and weight of wheat, and all grain depends on the quantity of gluten it contains, the best wheats containing the greatest quantity of gluten, and the smallest quantity of starch; its weight and value as an article of food, depending on the relative proportion of the two ingredients.

The following tables prepared by Sir H. Davy, give the result of an analysis of various kinds of corn, and they may in some degree as-

sist the agriculturist in forming a judgment on the quality of the seed to be sown :—

	Starch.	Gluten.
100 parts of full grained wheat sown in the autumn yielded . . .	77	19
100 parts of wheat sown in the spring	70	24
100 parts of Barbary wheat . . .	74	23
100 parts of Sicilian wheat . . .	75	21
100 parts of full and fair Norfolk barley	79	6
100 parts of Suffolk rye . . .	6	5

ON THE ORIGIN AND ASSIMILATION OF NITROGEN.

The analysis above given must amply demonstrate the fact, that nitrogen exists in the most valuable part of the vegetable structure, viz. the seeds. The first and most important question therefore is, how and in what form does nature furnish nitrogen to the various parts of plants?

There is not the slightest reason for believing that the nitrogen of the atmosphere in its simple state, takes any part in the process of assimilation in plants or animals; on the contrary, it is known that many plants emit the nitrogen which is absorbed by the roots, either in its gaseous state, or as atmospheric air dissolved in water. And also, it must be stated, that the nitrogen of the atmosphere cannot by any known chemical process be made to unite with any other gas than oxygen. But it is also known that nitrogen united with hydrogen and

thus forming ammonia, enters largely into the composition of vegetable gluten, and that this compound is invariably evolved in the decomposition of animal matter.

Ammonia is farther the simplest of all the compounds of nitrogen and hydrogen, and under all circumstances, when these two gases are disengaged in contact, the one with the other, they unite together to form ammonia.

As all animal matter consists principally of nitrogen, it must therefore in its decay yield it again (combined with hydrogen in the state of ammonia) to the atmosphere, and when the vast amount of animal matter which is constantly in a state of decay is considered, our wonder at the source of its supply will cease.

The ammonia thus liberated or formed by the decomposition of animal matter enters the atmosphere in a gaseous state, which combining with the carbonic acid gas, which, as exemplified in the preceding chapter exists also abundantly in the air, forms carbonate of ammonia.

Ammonia in its gaseous form, as well as in all its compounds with carbon, is exceedingly soluble in water; hence, it cannot long remain in the atmosphere, but must be dissolved and carried into the earth by the first rain which falls after it is evolved.—Hence also rain water must at all times contain ammonia, though not always in equal quantities. It must be greater in summer than in winter, from the double cause, that the showers are more rare in the former case than in the latter, and also

that the decay of all animal matter takes place with greater rapidity during the increased heats of summer, and it may be that to this cause is to be attributed the grateful feeling of the purity and freshness of the air which cannot fail to have struck even the most insensible, when a long summer's drought is terminated by a refreshing shower.

The author before quoted,* and whose work is again recommended to all who wish to master the subject under consideration, here enters into a variety of calculations to prove the extent to which ammonia exists in the atmosphere. It is hardly necessary for us here to follow all the details he gives, but the result may be acceptable.

It is calculated that if a pound of rain water contains only the fourth part of a grain of ammonia, and this is a low calculation, then that a field containing 40,000 square feet, would receive 80lbs. of ammonia annually, presuming that the fall of rain over such a surface amounted to 2,500,000 pounds, the quantity which on an average usually falls on such a space. This is a larger quantity of nitrogen than would be required by a crop of copse wood, hay or turnips; but less than a field of corn including the straw and roots, contain; and it must here be stated, that although this quantity of ammonia would be dissolved in the rain that may fall, still some portion of it would again enter the atmosphere with the water

* Liebig.

which might be evaporated, and also that the ammonia which is thus abstracted from the atmosphere, would as constantly be supplied by the decay of animal matter.

The ammonia thus dissolved and carried mechanically into the earth, is then absorbed by the spongelets of the roots, and in the course of its assimilation by the plant, enters into combination in a variety of ways, forming the various substances containing nitrogen, such as albumen, gluten, quinine, &c. into all of which it is known to enter from the ultimate analysis to which they have been subjected. It now only remains to be considered, as far as proving the presence of ammonia is required, whether plants in the various processes to which they are subjected to render them useful to mankind, ever give off ammonia; if it be found they do, the proof will be regarded as certain, and the other circumstances connected with nitrogen will at once be discussed.

It is accordingly found that the juices of the maple tree and the birch, when mixed with lime, which decomposes the compound containing the ammonia in such juices, emit a strong smell of ammonia, and in the manufactory of sugar from the beet-root, such a quantity of ammonia is given off, as to strike every one who has ever entered such an establishment, and the products also of all medicinal herbs, whether produced by distillation or consisting of extractive matter, yield ammonia during such processes. The sap also which exudes from the vine when cut, being first mixed with muriatic acid

and then with lime, gives off ammonia in its free state.

All these examples must convince even the most skeptical that ammonia does exist in almost all plants.

Hitherto the presence of ammonia in the atmosphere only has been considered, but we shall now enter into detail rather more fully, as to the sources from whence the atmosphere derives its supply.

In the analysis before given it has been seen that the muscle or flesh of all animals is composed almost entirely of nitrogen, and that animal matter in its decay, always yields this substance in the form of ammonia; hence, if we reflect that a generation of a thousand millions of men is renewed every thirty years, and that in the same period thousands of millions of animals cease to live and are reproduced, the question will then arise, what becomes of the ammonia which must be generated by their decay? But the examination of this subject must be carried still farther, to show that the liquid excrement of all animals, and especially of those which are carnivorous, contains an excess of ammonia, in the state most useful for the assimilation of the plant, and in that state also in which it may most readily be applied and collected by agriculturists, for use as a manure.

It is desirable here to explain why it is that the liquid excrement, that is the urine of all carnivorous animals, is richer in this principle of ammonia than that of herbiferous animals. It has been previously noticed that flesh con-

sists almost entirely of nitrogen. Those animals therefore which exist on the flesh of other animals consume a much larger quantity of this nitrogen, than those which exist on vegetables alone, and the system of the former not requiring all the nitrogen for its support, the excess must be carried off by the natural vents, and accordingly it is found that in proportion as the animal is either carnivorous or otherwise, so is the urine rich in ammonia; and farther it is remarked that amongst herbiferous animals, in proportion as the food is rich in nitrogen, (and it has been shown that wheat and all grains contain that principle) so will be the contents of the urine.

Acting on this principle then, it is found that 100 parts of wheat grown on a field manured with cow-dung, (manure containing the smallest portion of ammonia) yielded on its analysis only 12 parts of gluten, whereas 100 parts grown on the same field, but manured with human urine (the manure containing the largest quantity of ammonia) yielded the maximum of gluten, viz. 35 parts.*

From this it will be seen that it is perfectly within the power of the agriculturist to make his crops nutritious or otherwise.

If manured with urine or with other manures, which will furnish a supply of this most important ingredient, the grain will be nutritious and heavy. If on the contrary this pabulum is not supplied to the growing crop, the

* Liebig.

grain may be equally large, but it will weigh lighter and be less nutritious. The agriculturist, therefore, has it in his power to grow his crops, his wheat especially, to suit his customers; for example, if he lives in the vicinity of a starch manufactory, where his wheat may be required for the purpose of making that article, it will be the more valuable, the less nitrogen and the more carbon it contains, but if required as an article of food, or for making vermicelli, the very reverse of this is the case, an abundant supply of nitrogen being the requisite to give it that quantity of gluten on which its value as an article of food entirely depends.

These results may be obtained from the same seed and the same soil, wholly by the application of the proper manures, viz. of decaying vegetable matter, in the one case to furnish a due supply of carbon for the wheat intended for the starch-maker, and of urine or the nitrates of soda or potash in the other case to supply the gluten for the miller.

These subjects will again come under our notice under the subject of manures. We now proceed to point out other matters connected with the supply of nitrogen or ammonia to the soil.

The solid excrement of animals contains comparatively very little nitrogen, especially that from herbaceous animals, as almost all the nitrogen contained in vegetables which is not assimilated in the passage of the food through the stomach passes off through the urinary passages in a liquid form. And as the value of

manure depends almost as much on the form in which it is presented to plants, as on the manure itself, it is desirable to notice that nitrogen when combined in this, the liquid state, has lost almost all its tendency to assume its gaseous form, and that it exists in urine in the state of carbonate urate and phosphate of ammonia, in those forms in which it is most easily absorbed and assimilated by plants.

Another source for the supply of ammonia to the vegetable creation, arises from the gases constantly emitted by volcanoes from their craters, and the fissures in their sides in all parts of the world, and which gases always contain ammonia to a greater or less extent.

Professor Daubeny supposes this to be one of the principal sources for supplying the increased quantity of hydrogen, which a constantly increasing number of living animals on the earth's surface must require, and the theory has this peculiar merit, that it obviates the difficulty of supposing the atmosphere to have been charged at any time in excess with this gas, and which excess has been gradually absorbed in the structure of the increased number of living animals, to which civilization has given birth in all parts of the world. It also tends to unite the whole scheme of the creation into one vast whole, and to reconcile our minds to these hitherto mysterious operations of nature, by explaining the intimate connexion that exists between volcanoes, and the living organization on the earth's surface. The former of which in their eruptions, and at all times, af-

ford, by the emission of these ammoniacal gases, a constant supply of an ingredient necessary for the continual increase of the animal creation.

To explain the theory of the causes which generate the ammoniacal gases in the bowels of the earth, would be foreign to the purposes of this work. It is sufficient to notice here, their existence and the benefits they are supposed to confer on the living organization of the earth.*

To this cause also, namely the evolution of ammoniacal gases in the neighbourhood of volcanoes, Professor Daubeny attributes the luxuriance which vegetation possesses in all volcanic regions. It may, however, be remembered that this luxuriance has already been attributed to the presence of the alkaline properties, which the disintegration of the volcanic matters in the soil affords to the plant, (page 28.) It is possible however and probable, that both these causes united tend to produce this result, which is especially observable in the neighbourhoods of Mount Etna and Vesuvius.

The effects produced by carbon and nitrogen on plants, and collaterally on animals, have now been explained, but there is one circumstance in the assimilation of these substances by animals in their food, which may not be misplaced to notice here.

It has been before stated that every part of a plant contains nitrogen as well as carbon, but

* See Daubeny's work "On active and extinct Volcanoes."

as an invariable rule, the seed of all plants contains a much larger quantity of nitrogen, than the leaves and stalks, and a lesser quantity of carbon, and inversely, the leaves and stalks contain a much greater quantity of carbon, and a lesser quantity of nitrogen. Now when a horse is fed on grass, his food consists almost entirely of carbon, and the result is, that when he has a sufficient supply he gets fat; that is, that particles of oily fatty matter are deposited on the muscles under the skin, but as it is well known, a horse in this condition is quite unequal to any work, and the least exertion reduces his bulk. But when the same horse under other circumstances is fed on corn, his food consists principally of nitrogen, and although he may never under this keep, get as fat as under the other, still the increase he does acquire will be pure muscle, or as it is technically called, sound flesh; and on this keep he can perform infinitely more work with less fatigue, than on food containing no nitrogen.

A more complete instance could not be adduced to show that animals as well as plants can only assimilate that food which is presented them: in the first case, carbonaceous matters being the food of the horse, carbon is deposited in the shape of fat; in the latter, when more nitrogen enters into the composition of his food, the deposit of muscle preponderates. So it is with wheat. With a manure that only supplies carbonaceous matter, starch is the result. With a manure containing nitrogen, gluten is formed—both cases being

completely analogous, and affording unerring proof of one simple and uniform law.

ON WATER.

Water is next to be considered, and its importance in every sense cannot be overrated. It acts in a triple way: First, by its moisture affording a supply of a necessary article in the economy of plants. Secondly, by its solvent properties, it is one of the means employed by nature for rendering salts and other solid matters in a fit state to be absorbed and assimilated by plants. And lastly, by its decomposition, it furnishes hydrogen to combine with carbon, nitrogen, and the various salts which enter into the composition of vegetable products, and restores its oxygen to the atmosphere, to supply the place of that consumed by man, and all animals in the process of respiration.

This is a mere outline of the important parts it performs, and therefore it will merit some farther consideration to comprehend its chemical analysis. In its ordinary state, water is never pure; that is, it always contains carbonic acid gas, the salts of lime, soda, magnesia, potash, and frequently ammonia; all of which are essentially useful to promote vegetation—indeed, water in its pure state, will not of itself support vegetable life, and its solvent power is, therefore, one of its most important attributes.

In its chemical analysis, water yields oxy-

gen and hydrogen in the proportion of nearly 89 parts of the former to 11 parts of the latter. It may be produced at any time artificially, by a mixture of these gases in their relative proportions, and then passing an electric shock through the mixture. This effects the chemical union of the two gases, and the product is water of the utmost purity, and of the exact weight of the two gases employed.

Part of the water when absorbed by plants, remains as a fluid in the substance of the plant, and is evaporated from the leaves after having deposited the salts it may contain, and yielded up all the carbonic acid gas it may have held in solution for the nutriment of the plant. Another part undergoes chemical decomposition, and is resolved into its elements oxygen and hydrogen; the former passes off through the leaves, and tends to supply the place previously occupied by the carbon absorbed by the plant; the latter, hydrogen, enters into composition with the carbon, and tends to form the resinous and oleaginous matter of the plant, and under other circumstances combines with nitrogen to form ammonia,—after carbon the nutriment the most necessary to the growth and development of vegetable life.

The most positive proof exists, that plants do decompose the water absorbed by their roots, and assimilate the hydrogen, from the fact that caoutchouc or Indian-rubber, the volatile oils, wax, and other matters, the products of vegetables, consist almost wholly of hydro-

gen without any oxygen, and that there is no other source from which this supply can be obtained.

The hydrogen, therefore, necessary for the formation of an organic compound, is supplied to the plant by the decomposition of the water absorbed by the roots. The process of assimilation in its most simple form, consists in the extraction of hydrogen from water, and carbon from carbonic acid gas. The oxygen resulting in both cases from such decomposition, being either assimilated in the production of the acid properties common to some plants, or rejected to supply the necessary waste, or to re-form water with the hydrogen emitted by plants in the process of decay.

Oxygen, the other constituent of water, and the vivifying principle of the atmosphere surrounding the globe, is one of the most active agents in nature—it is the supporter of combustion, the source of life to all living animals, and acting as the prime agent in decomposing other matters, and rendering it fit for other processes, it enters into compounds with almost every substance known, forming a class of substances called oxides, which from the variety of forms under which they are found, and the important new combinations they again enter into with other substances, may fairly be reckoned as the most prolific in nature.

The part this gas performs in the vegetable economy is certainly subordinate to that performed by carbon, nitrogen, and hydrogen; its

effects indeed seem rather to be of a negative quality than otherwise, resulting only in a deficiency of power, in the various classes of plants, to assimilate the carbon and exhale the oxygen set free by such assimilation; but in the effects it produces in rendering other matter in a fit state to become or afford the pabulum to plants, it is equally important with the gases before named.

All the oxygen gas set free in plants by the assimilation of the hydrogen and carbon, in the manner before noticed, appears under favourable circumstances, to be given off in its pure state, but when such circumstances are not favourable, when indeed the plant may be considered to be in an unhealthy state, from the absence of a sufficient quantity of light to allow the assimilation of carbon and the decomposition of the water, the oxygen then remains in the plant, and enters into combination with the salts and other substances it may find there, and gives its peculiar character, that of acidity, to the products of the plant.

A familiar proof of the effects of oxygen under such circumstances, is the sour acid taste and watery flavour which fruits possess when clouds and rain, during a cold wet summer, intercept the sun's rays and prevent the influence of light on the fruits.

In this case the water absorbed by the root of the plant exists in its watery state and gives the vapid flavour, whilst the carbon imperfectly assimilated and the oxygen thus set free,

not being exhaled, remains to give the acid taste fruits, under such circumstances invariably possess.

That such is the result of the absence of light and heat will be obvious, if it is considered of what the analysis of sugar consists, viz. carbon 43 parts and water 57 parts; thus, if plants, from the absence of that cause which enables them to assimilate their carbon and dispose of their oxygen, are unable to do so, the results must be as is found they are, that under such circumstances the acid taste must predominate over the sweet; and in corroboration of this view it may be noticed that the sugar cane, the plant of all others which yields the greatest amount of carbon, can only be profitably cultivated in the tropics, where a burning sun and unclouded sky enable it to assimilate a sufficient quantity of carbon to produce its due supply of sugar.

That the cultivation of the beet root in France is no argument against this view of the subject, can be satisfactorily proved from the circumstance that the moment the protective duties which long existed in France for the protection of the home manufacture were abolished, that moment the manufacture from beet root ceased, thus proving that a given quantity of labour in Europe could not produce the same quantity of sugar as in the tropics, simply because the climate is not sufficiently clear to facilitate the assimilating of a sufficient quantity of carbon.

There are several classes of plants which

assimilate oxygen, or rather oxygen enters into combination with the salts they contain, and gives them their acid taste; such plants are the common sorrel and the vine, the one yielding oxalic, the other tartaric acid; but in these combinations it must be distinctly understood, that although the acid seems to be and is a necessary consequence of the absence of light, and thereby a constituent of the plant, still that it never exists of itself, but always in connexion with some salt termed its base—and it is desirable farther to notice that whether that base be soda, potash, magnesia or lime, that provided a base exists (which hereafter will be noticed as a necessary constituent of the vegetable economy) the oxygen will unite with it to form its peculiar acid.

From this it may be inferred, that the presence of the base is always necessary for the assimilation of the oxygen or acidifying principle, that without such base no oxygen could be assimilated; but the base may and constantly does exist, where the plant is fully developed without any such assimilation of oxygen.

That these bases are the causes of the acidity of plants, may be demonstrated from the fact that the acid is always in proportion to its base, a definite quantity of the one combining with a definite proportion of the other; thus, in the grape for example, the quantity of potash contained in its juice is less when it is ripe than when unripe, so likewise the potatoe plant contains more potash before blossom-

ing than after.* The leaves are the part of the plant which contains the greatest quantity of these bases, and hence their absorption of a larger quantity of the gases forming the various salts met with in the vegetable tribe.

There are many other peculiar acids which are found by analysis to exist in the substance of plants, but as they do not exist *per se*, in a gaseous or other state, but as a general rule are composed of various proportions of oxygen combined with other gases and united with some base, it is not intended to pursue this branch of the subject farther, as the consideration of each peculiar acid would lead us far beyond the limits proposed. It is simply necessary to repeat that in almost every case oxygen forms the acidifying principle.

* Liebig.

CHAPTER V.

ON THE SOLID EARTHY SUBSTANCES WHICH ARE ASSIMILATED BY PLANTS.

THE solid earthy matters, such as potash, soda, magnesia, lime, silex, phosphorus, all of which perform important offices in the growth of plants, are next to be considered; and here it must be observed that these substances differ materially from the gases already discussed. In this latter case it has been seen how the gaseous bodies exist as solids, as liquids, and as gases, in each state performing important functions in the vegetable economy; but, in noticing the earthy salts, it must be distinctly understood that they exist only as solids, and that the soil exclusively contains them. Hence, the only way in which they can be absorbed into the plant is, by the spongelets of the roots when in a state of solution.*

The analysis of a few vegetable structures is

* This fact as a general rule is perfectly true; but the atmosphere over the sea contains a very small portion of the saline matter of the ocean in solution, which may serve to account for the circumstance that all plants growing on or near the sea-shore, assimilate soda in their structure.

now given, that the importance of these earthy matters in the vegetable economy may be fully appreciated.

100 parts of the ashes of wheat straw yield

Saline matter, principally carbonate and sul-	
phate of potash	22½ parts
Phosphate of lime	6½ parts
Silicate of potash or flint	61½ parts
Carbonate of lime, metallic oxide and loss .	9½ parts
	<hr/>
	100

100 parts of the bran of wheat yield 44 parts of the phosphates of lime and magnesia, 100 parts of barley yield 32 parts of these phosphates.—(*Johnson.*)

100 parts of the ashes of the grain of wheat contain 76 parts of these phosphates.—(*De Saussure.*)

The ashes of beech-wood yield 20 per cent. of their weight of the phosphates of lime and magnesia.—(*Berthier.*)

Nearly one-half the weight of the ashes of oak leaves consists of soda and potash.—(*De Saussure.*)

100 parts of the fir grown in Norway yielded on analysis,

Potash	14
Soda	20
Lime	12
Magnesia	4=50 parts or one half.

The above analysis of vegetable substances, must demonstrate that these earthy salts are

essential to the development of plants in a variety of ways.

First. As one or more of these salts is a component part of every plant that exists, it may be thence fairly presumed that its presence is absolutely necessary.

Again. Plants growing in a situation where these substances are not to be met with, are diminutive in size, their organs are not fully developed, and in many instances they perish altogether after having attained a certain growth; and lastly, soda, lime, magnesia, and phosphorus, enter largely into the structure of the bones and teeth; and as all animals are dependant on vegetation for their support, either directly or indirectly, and as no other means naturally exist for supplying these necessities to the animal frame, it is not, perhaps, saying too much, when it is humbly presumed that this property of plants, may have been intended as the means of supplying these substances to the animal frame. And if this view of the case is correct, it cannot fail to exalt our ideas of the harmony that exists in all parts of the creation, of the admirable adaptation of the means to obtain a given end, in thus making the necessities of one part of the creation serve as a benefit to the other.

It is here also worthy of remark, that plants generally possess the power of assimilating, either of the principal alkalis, soda, or potash indiscriminately, and either appears equally adapted to the nutrition of the plant; for instance, wheat manured with either the nitrates

of soda or potash, appears almost equally benefited; and this circumstance also shows a power of adaptation, which, in its results, is most beneficial.

ON POTASH.

Potash, the first in order of the salts existing in the soil, exists abundantly as a natural product. It enters into a combination with almost all the acids and gases, forming a variety of compounds differing materially from each other, but it is never met with in its pure state. In its natural state it exists most abundantly as a nitrate of potash; that is, potash combined with nitrogen and oxygen, and in this state it is found in almost every region of the globe; being, however, present in greater abundance as we approach the tropics. It is found in two states, the one in a perfectly crystallized state in the fissures of limestone rocks, &c. and the other as a salt in the vegetable soil of the earth. Calcareous strata, containing this crystallized nitrate of potash are found in France, Spain, Germany, South America, and the East Indies; and it is in the soil of the latter country especially, from that contiguous to, and existing in the valleys of the great rivers, that our principal supply is derived.

In its native crystallized state, it is formed by an efflorescence of the salt itself from the rock containing it, and in every instance where the rock is highly charged with this salt a

fresh efflorescence occurs every day. At a celebrated nitre cave, as it is termed, near Naples, the efflorescence formed a deposit of one inch in thickness in the course of a few days, and this, too, in constant succession the one deposit after the other.

A familiar exemplification of this efflorescence takes place when Roman cement is used; the delicate needle shaped crystals which appear on its surface a few days after it has been applied as an external coating prove, that the stone from which this cement is prepared must contain potash, which thus effloresces, and exemplifies the way in which the natural deposits of this salt are produced.

Spain of all the countries in Europe is said to contain the greatest quantity of nitre in the vegetable soil. Nearly one-third of the uncultivated lands in the southern and eastern provinces yielding a rich supply of it when treated in the following manner. During the winter and spring, the land is ploughed two or three times to the depth of two or three inches. It is then allowed to lie fallow until the middle of September when it is lixiviated or washed with water. The liquor is then evaporated down in the usual manner, and deposits a quantity of nitre, mixed however with from thirty to forty per cent. of common salt.

In Hungary there are several springs and wells so impregnated with this salt as to be quite unfit for drinking, and indeed in almost every soil in every country it exists to a greater or less extent.

England derives her supply of nitre exclusively from her East Indian possessions. Holland also does the same, and has done so for ages past; but the other Continental States, having no colonial possessions, being driven to their own resources to produce this article, have discovered a variety of means of producing it. In the course of these researches it was found that the superficial soil of farm yards, cattle stalls, cellars, privies, and other places long exposed to the vapour of putrefying animal matter, afforded a supply of this article, and farther that the supply was much increased when these soils were mixed with wood ashes. In consequence of these discoveries various oppressive laws were created in France and elsewhere, giving the crown a right and possession to these nitrous soils wherever they might be found, and companies were formed and charters granted for the supply of this necessary article to the government magazines, but as a necessary consequence the land became impoverished from the abstraction of one of its best manures, and the vexations and annoyances to the parties subject to these extortions became so vehement, that a commission was appointed by Turgot, the then Minister in France, of which Lavoisier was the head, having for its object to discover the best means to obtain a supply of this article. The following is believed to have been the manner in which this important article was produced, or at all events these means may readily be adopted for forming it.

The nitre beds in France are composed of nitrous earth taken from farm-yards, stables, privies, &c., of street sweepings, mild calcareous earth (chalky soil) or old mortar, plaster, or even of the sweepings of roads paved with limestone, of animal matter, such as night soil, blood, refuse from the skinner's or tanner's yards, offal, &c., and of vegetable matter, such as straw, stable litter, saw-dust, spent tanner's bark, leaves, &c., these are all mixed together in somewhat casual proportions, care being taken that a sufficient quantity of calcareous matter is present, the heap is then made up into a long bed, protected from the weather by a suitable roof, and is then duly moistened with putrid water or urine. In this way a large quantity of nitrate is every year produced by lixiviation, but great part of it is now in the state of nitrate of lime, and it requires the addition of a quantity of wood ashes to supply the necessary potash, and convert the result into a pure nitrate of potash, or the wood ashes might be added at the time of forming the bed, using only a small proportion of the calcareous earth, and this would at once combine and produce in the soil the desired nitrate of potash.

The proportion of nitre afforded by these beds is about 12 ozs. for every 100 lbs. of material employed, but the proportion varies both above and below this quantity, according to the value of the materials employed to form it, and the care subsequently taken in managing it.

There are many other modifications of this manufacture, some infinitely more scientific in their process, and requiring greater care during the different stages of the manufacture, but the one now quoted appears to combine great simplicity with a certain result, and one moreover which is quite within the reach of all agriculturists, to some extent at least, and its adoption as a source of manure to their farms generally, would be sure to prove a profitable speculation, and if this result should only be attained in a few instances, where these things are now neglected, the object of this work will be accomplished.

It may here be desirable to explain why wood ashes are necessary for the successful production of this salt. It has been stated that all animal matter in its decay yields a copious supply of nitrogen to the atmosphere or soil, all of which would readily combine with potash, to form the nitrate of potash, were it present; but as the supply of nitrogen, is under almost all circumstances infinitely more abundant than the potash, the wood ashes are added to afford such supply and to fix the nitrogen which would otherwise be evolved in a gaseous state.

This is the constant practice in the East Indies; where the excess of nitrogen after having combined with all the potash existing in the soil, forms a new compound with lime, called nitrate of lime, and to correct this, wood ashes, containing carbonate of potash, are added, and this effects a double decomposition. The nitrogen of the lime unites with the pot-

ash, and the carbon of the potash unites with the lime, thus forming carbonate of lime and nitrate of potash.

In this case it may appear that, although little or no potash might be present, still that all the nitrogen would be absorbed by the lime, and hence it might be inferred, that as far as the agriculturist was concerned that no loss would accrue to him; but this is a dangerous doctrine, it is not only a necessary condition that a certain substance should be present in a soil to become the nutriment of the plant; but it is also necessary that it should be present there in that state in which it most readily furnishes such nutriment, and in the present case, with the knowledge already possessed, there is no doubt but that the nitrate of potash is a more efficient manure than the nitrate of lime.

Potash is, as we have previously noticed, never met with in its free state, but always in combination with some acid or gas. Thus it has been explained that the potash contained in wood ashes is a carbonate of potash, whilst that in the soil is a nitrate of potash, and it exists in an impure state, in a variety of combinations, but the two just specified are those most frequently and commonly met with. In its ultimate analysis nitrate of potash, is an oxide of the metal potassum combined with nitrogen, and the carbonate of potash is an oxide of the same metal united to carbon. This is not exactly the way in which it would be chemically expressed, but it is sufficiently clear and distinct for the purpose here required.

In whatever state it may exist in the soil, its

assimilation by the plant is the same, that is, it must be taken up by the roots when in a state of solution, and thus be distributed over the whole plant, when its decomposition will at once take place; in the case of the nitrate of potash, the nitrogen is set free to combine with other matters to form the gluten of the seed, and in the state of carbonate, the carbonic acid gas is assimilated as carbon, giving off the oxygen, and in both cases the potash is set free to form a base for the peculiar acid of the plant, be it malic, oxalic, or any other.

ON SODA.

The next salt in the solid substances necessary for the development of plants is now to be explained, and its presence is so universal, that the remarks we have made respecting potash will equally apply to soda.

It is found in almost all soils combined with potash, but generally in a lesser proportion and as a muriate of soda instead of a nitrate.

The sea is the great source of this salt, and all marine plants, as well as plants growing on or near the sea coast, assimilate this salt instead of potash. It exists also abundantly combined with chlorine (common salt) in various parts of the globe, and in our own country the native rock salt is a source of a considerable commerce, and is the basis of many changes.

Soda like potash is never found in its pure state, but always combined with some acid, indeed it is with difficulty obtained in any other form.

We purpose here to consider this salt in the three states only in which it exists most abundantly, viz.—as common salt, a combination of chlorine and sodium; common soda, such as is sold in the shops for washing and other purposes; and nitrate of soda:—all of which have an important influence on vegetation.

In its combinations with other acids this salt is quite unimportant as far as its uses in agriculture are concerned.

Common Salt.—The first state of soda that comes under our notice is a compound of chlorine gas and sodium, in the proportion of 36 atoms of the former to 24 of the latter. It exists abundantly as a native product in many parts of the globe; but in others it is almost deficient.

In our own country it forms an immense source of traffic, not only with those places distant from its sources, but also with many European states where it does not so abundantly exist.

There are three sources from which this salt is derived, first as a native rock salt at Northwich in Cheshire, next from the brine spring at Droitwich in Worcestershire, and lastly by evaporating the sea water and thereby obtaining the salt held in solution.

Some idea may be formed of the immense

consumption of this necessary article by stating that upwards of 140,000 tons of salt are annually exported from Liverpool alone, and that from the salt springs at Droitwich, upwards of 16,000 tons more of pure salt are annually produced, to say nothing of the immense quantity manufactured from sea-water in various parts of the kingdom. The first kind, the rock salt, is extensively used for agricultural purposes, principally for the use of sheep and cattle generally, and there can be no doubt of the utility of this substance for them, if only exhibited by the fondness of sheep, horses, and generally all herbiferous animals for it. The last two kinds, obtained by evaporating the brine to the state of common salt, are those which are generally used as a manure, and perhaps there is no one article that has been more the subject of discussion than this, and one about which greater uncertainty seems even now, notwithstanding all that has been said, to prevail. It is not our province to add more here on the subject, than to express a decided conviction that its use in many cases would be very beneficial; but greater care is perhaps necessary in its application than in any other of the salts of soda.

One complaint that is made constantly against the use of this salt is, that it produces absolute sterility if the quantity is at all in excess, and the fear of this result interferes with its use. This effect arises from the caustic nature of the gas with which the soda is combined, viz. the chlorine, and as this body

is not necessary to vegetable life, it acts when in excess as a poison.

Various suggestions have been made for modifying this effect of the common salt. One of the latest writers on the subject is a Mr. Henry Kemp of Poole, who states that he has discovered a ready and efficacious means of decomposing common salt and neutralizing its caustic property, and he speaks of the success that has attended its use in his own immediate neighbourhood as having been very decided. This is precisely what our previous reasoning would have led us to anticipate, as when decomposed, the noxious property of the gas is got rid of, and its beneficial property only retained to act on vegetation.

Mr. Kemp unfortunately, in his pamphlet, does not say how or in what manner he has succeeded in thus decomposing salt at such a rate of expense as would allow^b of its use in agriculture. He merely states the fact that he had done so, and speaks of the beneficial results he has attained, but declines describing his process unless he is remunerated for it. Whether he has as yet divulged this secret, or whether there is any probability of his doing so is not known, as, since the publication of his pamphlet, which deservedly attracted attention at the time (1832,) we have heard nothing about it.

Mr. Johnson, in his valuable work on manures, gives all the information that is known, and a great variety of experiments that have been made with common salt, and to

that work the reader is referred for farther information as to the success that has attended its use,—the quantity applied,—its mode of application, &c. Here it is only our province to explain the chemical effects produced by this substance on vegetation.

Common Soda is an impure sub-carbonate of soda, that is, soda united with carbonic acid gas. In this state it is sometimes found in nature, but the principal source of supply arises from lixiviating the ashes of burnt sea-weed, such as kelp and barilla, &c. Extensive manufactories exist for the production of this necessary article in Scotland and various other parts of the kingdom, and it is also produced as a refuse matter from other salts of soda, in the alkaline manufactories throughout the country.

It is to the presence of this salt that the fertilizing properties of the ashes of sea-weed may be attributed, and its addition to the compost heaps spoken of in page 82, would furnish the alkali necessary for fixing the nitrogen, and thus afford a more certain result than can be obtained from the use of wood ashes. The combination however in this case would be a nitrate of soda instead of nitrate of potash.

The use of this salt as a manure would be valuable to any soil deficient in alkaline matters, to which by its solution in the first rain it would afford an ample supply, whilst the carbonic acid gas, that would at the same time be

set free, would furnish a necessary ingredient in the economy of plants.

Its use however as a manure is very limited, the results it is presumed not being adequate to its price (about £11. per ton.) It might however in certain cases be found a ready means of supplying an alkali to the soil, and we are inclined to believe that it has not in all cases received that attention from agriculturists which its merits would warrant.

Nitrate of Soda.—This salt, which of late has attracted so much attention amongst agriculturists, is a native production of Peru. It is there met with in large quantities about fourteen leagues from the port of Iquique, where it forms a stratum from two to three feet thick, lying close beneath the surface, and following the margin of a grand basin or plain elevated 3300 feet above the level of the Pacific Ocean, but which nevertheless appears at one time to have been a lake or inland sea.

When first introduced into this country, some ten or twelve years since, a few tons only were imported, and then not with any view to its use for agricultural purposes, but merely as a substitute for the nitrate of potash, in making nitric acid, &c., and even Dr. Henry in his *Elements of Chemistry*, (published in 1829,) when speaking of this article says, “its only use is as a substitute for gunpowder in making fireworks.” So little can even the first abilities foresee the uses to which any substance may be subsequently employed.

The few tons thus imported laid on hand for some time, no profitable use having been discovered for the article, when it was suggested that it might be profitably employed for agricultural purposes. A trial was made, and the immense benefits resulting from its use became at once apparent, and from that time to the present a continually increasing demand for it has existed, which has raised the annual importation into the port of Liverpool alone, to upwards of 55,000 bags, and at the present time there seems to be no limit but its price to its universal use.

In its analysis 100 parts yield,

Nitric Acid,	58 parts.
Soda,	42 parts.

and 100 parts of nitric acid are again resolvable into

Nitrogen,	26 parts.
Oxygen	74 parts.

So that each 100 parts of the nitrate of soda, contains about 15 parts of pure nitrogen.

It would be foreign to our purpose to note here the various results that have followed the use of this manure, and even were it not, it would be a work of supererogation, as it is now so established and so universally used, that each parish almost throughout England can furnish some evidence of the benefits derived from its use.

Our object here will be to prove that grasses

and corn of all kinds, and wheat especially, are benefited to a great extent by the nitrate of soda, and that its use materially increases the weight of the wheat itself, and by a necessary consequence its nutritive properties.

It has been demonstrated (page 58,) that the gluten of wheat is that part of the grain which contains the greatest nourishment, and that which gives to wheat its great specific gravity. Now if we can establish the fact, that the use of this manure not only increases the quantity, but at the same time improves the quality of the corn; we think we shall have said all that need be necessary to urge its continued use, and if millers and bakers especially, the parties to whom, in a commercial point of view, these attributes are indispensable, were fully cognizant of the individual benefit they, as well as the public, would derive from the application of this substance to the corn, they would purchase no other wheat, but such as had been so manured.

To prove this position we must go into some detail, and illustrate this subject with the results of some experiments introduced by Professor Daubeney in his third lecture delivered at Oxford.

In an analysis of 100 parts of two different specimens of wheat, which were grown in the same field, one of which had been dressed with the nitrate of soda, and the other not, the result was—

	Wheat on which nitrate was used, gave		Wheat on which no nitrate was used, gave
Bran	25	—	24
Gluten	23 $\frac{1}{4}$	—	19
Starch	49 $\frac{1}{2}$	—	55 $\frac{1}{2}$
Albumen	1 $\frac{1}{4}$	—	$\frac{3}{4}$
Extract, loss and water .	1	—	$\frac{3}{4}$
	<hr/> 100		<hr/> 100

Thus it is seen that the wheat so nitrated, contains $4\frac{1}{4}$ per cent. more gluten, and $\frac{1}{2}$ per cent. more albumen than the wheat not so nitrated; and, as it has been stated, that gluten is the substance to which flour owes its nutritious qualities—this alone would prove our position. But if we carry our investigation farther, and see its results as to the real produce of bread, we shall be more fully convinced than ever of the utility of this manure: and, here again, we resort to experiments made by the same distinguished professor for an elucidation of this fact.

Three pounds and a half of flour, made from wheat dressed with nitrates, produces 4 lbs. 14 ozs. of bread; whilst three and a half pounds of flour, made from wheat where no nitrate was used, yielded only 4 lbs. 4 ozs. of bread: thus leaving ten ounces of bread in favour of the wheat so nitrated.*

* The flour from which Professor Daubeny's experiments were made, was obtained from wheat manured with the nitrate of potash. But still as wheat manured with the nitrate

No other argument can be necessary to convince even the most skeptical of the value of this article as a manure. Its benefits to the individual, as well as to the nation at large, are incalculable; and it only ought to serve as a stimulus to all parties to exert their influence in extending its general use.

The action of soda and potash on vegetables, and the way in which they act on vegetable life are so similar, that a description of the one will suffice for both. It is intended, therefore, to describe the action of soda only.

It has been stated in the analysis of various plants, that both these salts exist in almost all plants, generally as carbonates; but potash frequently combines with other acids, and is then found in various states. Neither ever exist in the structure of plants as nitrates; this variety being generated only by the process of decomposition of vegetable matter in the soil.

When the ashes of burnt vegetables, or decaying vegetable matters in any state, are scattered over a field as manure, the salts of soda or potash they may contain are dissolved by the first rain, and carried into the soil, and then are absorbed by the spongelets of the roots of the plants, and here the first process in their assimilation commences. If the salt is present as a carbonate, it is decomposed; the soda being assimilated by the plant in connexion

of soda is equally rich, as a general rule, in gluten, this circumstance does not at all affect the conclusion we have arrived at.

with the peculiar acid each plant contains, and the carbon thus set free, performs the functions attributed to it in a preceding chapter.

But if the soda is applied in the state of a nitrate, as is now generally the case, especially as a top dressing for white crop, its action is somewhat different.

In this state the salt, after having been dissolved and absorbed by the roots, is decomposed, but in this latter case, nitrogen is assimilated to form the gluten in the seed, and to enter into the other parts of the plant.

It is a popular opinion that these salts act on the various soils as stimulants, and that although they may increase the vegetation for a season, still that their use is injurious, as they exhaust the soil in the same degree in which the crops are improved. A greater fallacy than this it is scarcely possible to conceive, and even had we not the experience of facts to fall back on, it could be satisfactorily proved that the action of soda and potash, and especially of the nitrates of these salts, are of themselves the cause of the increased luxuriance, and that the soil is, and must be benefited by their application. Thus, when the nitrate of soda is applied as a top dressing, it is absorbed and decomposed, as already seen; and, of itself is the cause of the increased weight of the crop and the luxuriant vegetation. It may possibly, and does by giving increased vigour to every part of the plant, enable it thereby to absorb more nutriment from the air, but it has been already, and it is hoped, sufficiently explained,

that plants after a certain stage, derive their principal nutriment from the atmosphere, and not from the soil; and the increased action that is given to plants from the supply of nitrogen and soda, enables them to assimilate more carbon from this source.

A farther proof that the application of nitrate of soda has a contrary effect, is known from the circumstance, that crops growing on land that had been dressed during the preceding year with this manure, have during the second season showed the beneficial result of the application, in increased luxuriance, and by their rank deep colour; a circumstance entirely to be attributed to a portion of the manure still remaining in the soil. Another circumstance corroborative of the truth of these opinions may be collected by reflecting on the routine that is too frequently observable on farms, where a judicious system of agriculture is overlooked; for instance, many crops are annually removed from a certain pasture, and no manure applied until the land becomes entirely exhausted, and when in this state, the application of the nitrate of soda or potash, at once restores abundance and a rank vegetation. In such instances as these, it cannot force the soil, because on all hands it must be admitted that the land was entirely exhausted; any increase, therefore, must be entirely attributable to the efforts produced by the presence of these salts. The same remarks will apply to other manures, such as chalk, lime, &c. and will be mentioned under their respective heads.

It is only necessary farther to remark, that every crop removed from a soil contains these salts, and unless they are again restored to such soil in the state of manure, or as a pure nitrate, the land must become impoverished and eventually barren.

In the few cases where the nitrate has failed to produce the effect anticipated, it may possibly be attributed to the absence of the phosphates of lime and magnesia, and the silicate of potash, all of which are essential to the growth of a white crop, and without which, howsoever abundant the nitrate may be, no crop could be produced.

It may be, but of this further experience is necessary, that the application of these salts, the nitrates of soda and potash, stimulates perennial plants to such an excess, that they are unable for a time after the action of the salt is over, to compete with similar plants not exposed to its action; but this requires much more observation to confirm the fact, and it does not in any way apply to its use on those crops where it is not only most needed, but at the same time most beneficial. It is only mentioned here to explain how it is, that in one or two cases where the nitrate of soda was applied during the last spring (1841) to old pastures, and where it produced the most marked and decided effect, that, after the grass was cut and the produce harvested, the after grass was a long time before it came away, and that the grass not manured with this soda then appeared the most luxuriant. This effect however was

only for a time, but it serves to convince us that the stimulus is to the plant and not to the soil.

ON PHOSPHORUS.

This elementary matter is never found in its pure state. Combined with oxygen gas, it forms phosphoric acid, and this again united with such bases as lime, soda, magnesia, &c., forms the salts termed phosphates, which are met with in animal, as well as in vegetable products.

Phosphate of lime is, as will hereafter be noticed, the principal ingredient of bones, of which it forms the hard part. A native phosphate of lime occurs abundantly in Spain, under the name of Apatite, and other native combinations of this acid occasionally are met with.

Phosphorus is an ingredient in urine, and affords another argument in favour of the use of this matter (hereafter to be noticed) as a manure; as the presence of the phosphates is essential to the growth of vegetables, especially of wheat, barley, oats, and rye, in the grain of which it always occurs, and without which no such crop could be perfected, and from this source also the human frame derives its supply of this necessary matter.

The native phosphates exist in a greater or less degree in all soils, and vegetables there find the supply they require for their growth and development. But as this essential is as easily exhausted by a crop, as the other salts

spoken of, it behoves the agriculturist to see that a return of this matter is made to the soil, and in no way can it be either more efficiently or more economically restored, than by the use of urine and animal excrements.

The specific action of the phosphates of lime and magnesia, the two combinations in which it is most frequently met with will be described under their respective heads, any notice of them here, therefore, would be superfluous. It is simply necessary to note that the phosphates contained in the urine of all carnivorous animals are the excess over and above that required to supply the waste of the body, and which is thus thrown off as refuse matter.

ON LIME.

Lime exists abundantly, combined with various acids, in all parts of the globe, and there are few districts in which this essential substance is not abundant. Indeed so universally diffused is this salt, that every plant that has yet been analyzed, with only one exception, contains a portion of lime in some state or other, which it must have derived from the soil in which it grew. Wheat in flower, when ripe, the straw, the bran, all yield lime when analyzed; so likewise do barley, oats, vetches, the leaves of various trees, the bark, timber, &c.; indeed this substance is so universally present in all parts of the vegetable structure, that it may be fairly assumed to be an integral

portion of all, varying however according to the quantity existing in the soil in which the plants are cultivated.

One of the most obvious purposes it serves, is to give stability and substance, from its earthy nature, to those parts of the plant, which otherwise would not perhaps have sufficient strength to perform the functions allotted to them; but that it possesses other properties, there is little doubt, as it is found not only in the stalk, but in the leaves, fruit, and indeed in almost all parts of the plant.

Carbonate of Lime, that is, lime combined with carbonate acid gas, is the state in which the substance most commonly exists; in this combination it is known to us under the names of marble, chalk, marl, limestone &c., all being lime combined to a greater or less extent with carbonic acid gas. Chalk, we believe, is the substance of this class which is most commonly used as a manure, or in promoting vegetation. We therefore shall confine ourselves to describing its use, and its mode of action, but, with a few slight modifications, the same remarks will apply to any of these substances.

In its ultimate analysis chalk yields,
 55 parts of lime, and
 45 parts of carbonic acid gas, } in every 100 parts.
 and some extraneous matter, such as silex, and oxide of iron.

In this state it is very sparingly soluble in cold water, but if water charged with carbonic acid gas is present (and all water, as we have before seen, (page 69) does contain this gas,)

its solvent powers are much increased, and in this way it is absorbed by the spongelets of the roots, and assimilated by the plants; and its slow solution by water is one reason why its effects are so lasting when applied to a soil. Chalk has been and is extensively used as a manure, and even in some cases on calcareous soils themselves with advantage.

It produces a mechanical as well as a chemical action wherever it is applied. Mechanically by dividing the soil, and rendering it more light or friable as it is termed, and chemically by absorbing moisture from the atmosphere and giving it out slowly as vegetation subsequently requires it, as well as by its solution affording a necessary ingredient to the development of all plants.

All these carbonates of lime when burnt lose their carbonic acid gas, and pure lime is left. The heat destroying the affinity, previously existing between them. Lime in this state is most extensively used for agricultural purposes, and as it loses nearly 44 per cent. in weight in burning, it may be well worth the consideration of those agriculturists who live at a distance from chalk to know whether in this state it may not be equally beneficial, as the saving in carriage on such a substance, is a material item in the expense.

The same remarks we have applied to chalk will equally explain how lime acts on vegetation.

It is soluble to a slight extent in water, more largely in cold than in hot water, and

more so in water charged with or containing carbonic acid, than in other,—it is then absorbed and assimilated by the plant; but it also is supposed to assist materially in decomposing dry hard vegetable matter, from its great attraction, when in this its caustic state, for the gases combined with other substances, and hence its use on peaty soils. Care should always be taken to procure this article as fresh and as perfectly burnt as possible, and as short a time as possible before it is made use of, as lime when only just taken from the kiln can be said to be pure, for immediately on its removal it begins to absorb the carbonic acid gas of the atmosphere, and to resume its original state of a carbonate of lime.

It has also a great affinity for nitrogen, with which it readily unites to form nitrate of lime, and although in this state it still produces in a moderate degree the effects produced by lime, its effects are not superior to chalk, which generally can be obtained at a less cost.

Sulphate of Lime, or Gypsum composed of sulphuric acid and lime, the next in order and in importance of the compounds of lime, occurs native in various districts of England, the most abundant quarries or pits being in Derbyshire. It is found also abundantly in the neighbourhood of Paris, from whence its popular name, “plaster of Paris,” is derived.

The beneficial results arising from the use of this manure on grass lands are admitted on all hands, and even in the few instances where no good results have followed its use, it

has too frequently arisen from the presence of this earth in the native soil itself, where consequently its application could do no good; and a more urgent argument for the necessity of a knowledge of chemistry to the agriculturist, than is furnished by this simple fact, which has occurred more than once in the history of this manure, cannot be cited.

The action of this earth, gypsum, in producing such luxuriant effects on grasses arises entirely from its power of absorbing the ammonia of the atmosphere (page 60,) which important article by its solution in water and subsequent absorption by the spongelets is thus yielded to the plant itself.

The ammonia existing in rain water is, whenever it comes in contact with gypsum, at once absorbed, and a new compound is formed called sulphate of ammonia. In this state the ammonia is fixed, that is, it has no volatile properties, and water is the only thing needed to dissolve this new compound for the use of vegetation, and the absence of moisture will frequently explain why gypsum produces either a less effect or no difference at all in dry fields or meadows. The lime disengaged by this action is either dissolved with the sulphate of ammonia and absorbed by the roots, or it combines with other gases to form carbonate or nitrate of lime.

In order to give some idea of the effect to be produced by gypsum, it may be stated* that

* Liebig.

100 lbs. of gypsum has the power of fixing as much ammonia as 6000 lbs. of horses urine, even assuming that no loss would occur in the absorption by the plants of all the nitrogen of the latter manure. And if again it is admitted, and analysis proves that it is so, that 100 pounds of grass contain one pound of nitrogen, then every pound of nitrogen that is added to a soil, must produce 100 pounds of grass, and this increased produce is effected by little more than four pounds of gypsum.

The decomposition of gypsum by this process of absorption of ammonia, goes on very slowly, and this explains why the action of gypsum lasts for so many years.

The benefits arising from the use of burnt clay and the fertility of ferruginous soils may all be explained on the same principle, the power these matters possess of fixing the ammonia of the atmosphere, and subsequently by their solution in water, yielding it to the plant; indeed all soils, to a greater or less extent, possess the power of absorbing gaseous matter. It has been proposed to sprinkle sulphuric acid over calcareous soils to produce gypsum artificially, but the experiment has not, we believe, ever been tried.

It would be alike foreign to the purpose intended in the publication of this treatise, and useless, to cite examples of the beneficial effects which have resulted from the use of this valuable agent. All who wish to know every thing that relates to this and other manures will do well to consult Mr. Cuthbert Johnson's work on Fertilizers.

Phosphate of lime, consisting of lime 55 parts, and phosphoric acid 45 parts, enters largely into the structure of turnips, wheat, and many other crops. It occurs in many composite rocks, and it exists in its native state in Cornwall, in the north of England, and Spain, and is known by the name of Apatite; in the latter country it is abundantly present in Estremadura, where it is so common, that the divisions of the fields are said to be formed of it. In this state, however, it has never been used as a manure, we are therefore unable to speak positively as to its value; but reasoning from analogy, from the beneficial effect that this substance produces in the state of bone dust, there can be little doubt but that its use would prove highly advantageous.

The chief source of this manure in this country arises from the use of bones; the beneficial effects of which are attributed almost entirely to the phosphate of lime they contain. In their analysis, calcined bones yield between fifty and sixty per cent of this earth, and when it is found that phosphate of lime exists in almost every part of the grass tribe, in the seed, the bran and the stem, there is every reason to believe that this is the fertilizing property; and added to this, we have the fact before us, that bones, whether used fresh from the slaughter-house, without having been subjected to any calcining process, whether taken from the kitchen after having been either boiled or roasted, or from the manufactory, where every portion of oil or fatty matter is extracted, or from caves, or other existing deposits of bones,

where they must have laid for centuries, that bones taken from any of these sources, crushed and applied to the land, are equally beneficial in their results.

Having thus established the presence of this earth in plants, and its importance as a stimulus, the next consideration is to explain its mode of action; and more difficulty exists in doing this satisfactorily, than in any of the previous substances that have been noticed.

Phosphate of lime is described as an insipid white powder, *insoluble* in water, but soluble in dilute nitric, muriatic, and acetic acids, but this does not at all help to solve the question as to how it is to dissolved in the laboratory of nature. It is supposed either that the salts and gases which (page 70) are constantly present in water, have a sufficient solvent power to enable the plant to take up this substance, or that the electricity which we know is always present, during any change in the state of matter; and consequently always in action during the germination of seeds and the growth of plants, that this agent exerts an influence in some way or other to allow of the solution of this phosphate of lime in water.

It is admitted at once and frankly that the theory here set forth is liable to many objections, but so is the subject, and we are by no means yet in a position to explain how the solution and assimilation of this substance is effected.

Nitrate of lime, (nitric acid 66 parts, and lime 34 parts,) exists also in a state of nature. There it is formed by the nitrogen of decaying, ani-

mal and vegetable matter uniting itself with the calcareous matter of the soil ; it is also found to exist in the plaster of old buildings, which have been long inhabited, especially it is abundant in the plaster and cement of walls and ceilings near privies, where, from the quantity of nitrogen constantly exhaling, a considerable portion is assimilated.

Of its use as a manure nothing can be said ; it is not known to exist in any state in plants, and the few experiments I myself have instituted with a view to test its effects, have been so unsatisfactory as to leave little hope of its being beneficially employed hereafter.

ON MAGNESIA.

Magnesia, the next earthy matter we have to consider, is a constituent of almost all plants, and exists abundantly in all parts of the world, in various states of combination. We have only to recognise it here in the state of a phosphate of magnesia, in which combination it is found in the grain of all white crops, and of which it forms a considerable part.

A native phosphate of magnesia is unknown, the magnesia which we find therefore existing as a phosphate in the corn and husks of all grain, must be absorbed in the state of a carbonate, that is, dissolved in water by means of carbonic acid gas, or it may be taken up in combination with other acids, in which state it is very soluble, and then being assimilated,

decomposition must take place, the carbonic or other gas being liberated or assimilated, and the magnesia united with the phosphoric acid derived from the lime, or from other sources, as has been explained when speaking of phosphorus.

Magnesia exists also abundantly in limestone, and care should be taken by every person about to apply a dressing of lime to his land to know whether the stone or chalk from which it may be burnt, contains magnesia or not, as its use combined with lime is very prejudicial to many soils, whilst on others, its use would be equally beneficial.

Sir Humphrey Davy explains satisfactorily the reasons why the magnesian limestone is to be avoided, or used with great care as a manure. The reasons he gives are, "That the magnesia of the limestone is much sooner deprived of its carbonic acid than the lime; and, that when applied to land, it rapidly absorbs the gas from the surrounding humus: but if there should not be a sufficient supply of this carbon, the magnesia will then remain in its caustic state, and in this state it acts as a poison to many vegetables."

Mr. Johnson also, in his able work before quoted, has proved that such is the effect of the magnesian limestone, and acting on Sir Humphrey Davy's experiment, he judiciously recommends its use to restore peaty soils, and *vice versa*, the use of peat as a remedy to land where the magnesian limestone has been applied.

ON SILEX.

Silex, or pure flint, is the next constituent of vegetable matter to be explained.

It may seem to those whose attention has never been called to the structure and constituents of plants, that the presence of this substance is impossible; but yet the analysis of wheat straw, which yields upwards of 60 per cent., (the remaining 40 parts consisting of carbonate of lime (chalk,) phosphate of lime, potash, or soda and iron) prove beyond all question its presence; and the mode which nature in her vast laboratory employs for the assimilation of this substance, will, therefore, be our next consideration.

Silex, in its pure state, is perfectly insoluble in water; but silex combined with potash, is perfectly so: indeed, there is a species of glass manufactured from these ingredients, which dissolves perfectly in boiling water. And as potash and silex equally abound in almost every soil, it only remains for us to endeavour to explain how this substance may be formed in nature; but this, however desirable, is with our present knowledge unattainable.

We know that nature has the means in her immense galvanic power, which is constantly in operation, in the powerful auxiliaries that she has in the summer's sun, the winter's frost, and the daily variations of moisture, to reduce the most obdurate substances to a state fitting them for change. And we must be content, at present, with the knowledge that such a power

is present, and that by its means combinations are produced; but the manner of their production is as yet a mystery.

It is, however, probable that a silicate of potash is formed by some process in nature, which is either entirely or sparingly soluble in water; and this admitted, the difficulty at once ceases. In this state it is absorbed by the spongelets of the roots, the silex is assimilated in the straw, and the potash exists to enter into compounds with the various other substances present, and to perform the functions elsewhere described.

Silex is one of the most abundant products in nature; it constitutes a principal ingredient in granite, it composes a large portion of the sand found in beds of rivers, and on the sea shore, and it enters largely into several minerals of rarer occurrence, such as rock crystal, quartz, cornelian, &c.

Its mechanical use in agriculture is very great, as it serves to render heavy soils porous, and open to the transmission of moisture, and with this view it is extensively used; although this action must not be confounded with the use of the calcareous sand in Cornwall, the western part of Ireland, and other places, where the benefit derived arises entirely from the calcareous nature of the sand so employed.

This then concludes the description of those substances which are assimilated by plants.

It has been showed, it is hoped satisfactorily, the sources from which these simples are derived, their mode of action, and the compounds they enter into, and the analysis of the various

vegetable products that have been given in treating of this subject, must convince even the most skeptical, how all-important these substances are; and that no plant or vegetable structure can ever exist without the agency of the simples thus imperfectly described.

Farther experience will probably tend to elucidate much that is now obscure in the processes nature employs, and each fresh discovery that is made not only simplifies the subject, but is a double step in advance; as such discovery not only tends to simplify what is already comprehended, but gives us a firmer footing on which to base our future operations.

CHAPTER VI.

ON MANURES.

To render the subject of the preceding chapters as complete as possible, it is desirable that the specific action of each individual manure should be perfectly understood. Without a full understanding on this point, it is impossible for the agriculturist to decide with a certainty of success on the manure for a certain crop, or the best management to be adopted, and although a keen habit of observation will and does go far to supply this deficiency; still an explanation of the peculiar action of each manure on the soil or crop, cannot but be useful, to say the least: and, in the majority of cases, such knowledge will be eminently serviceable to determine the time proper for the application of any particular substance, the quantity to be used, and the best manner of applying it.

Having thus premised, it only remains to say, that all substances, whether liquid or solid, which are applied to the soil to promote the growth and vegetation of plants, will be considered as manure; and although the subjoined list is far from containing all the matters thus made use of, still, a sufficient selection is given, from which the effects of others not mentioned may be inferred.

It is, therefore, proposed to consider these substances in the following order:—

Ammonia,	Guano,
Ashes—Wood,	Gypsum,
“ Coal,	Lime,
“ Peat,	Liquid Manure,
Blubber,	Night soil,
Bones,	Clarke's do.
Chalk,	Potash,
Charcoal,	Salt,
Dung—Farm-yard,	Saltpetre,
“ Birds,	Soda,
“ Dogs,	Soot,
Fish,	Urine,
Fish-oil,	Urate,
Gas liquor,	Woollen rags,
“ lime,	Irrigation.

Ammonia.—Already under the head “nitrogen,” (p. 60) this substance has been fully discussed, and the important part it performs in vegetable economy fully described, and to this article therefore we beg to refer the reader.

The chemical analysis of ammonia yields three volumes of hydrogen and one of nitrogen, and it is to the presence of this latter substance that the effects produced on vegetables are to be attributed. This combination is one of the most simple compounds of nitrogen that exists, and yet certain conditions are necessary for its union with hydrogen. It is not at all necessary here to detail what these conditions are, it is only necessary to repeat what we have previously stated, that the nitrogen of the atmosphere does not in any way combine with hydrogen to form ammonia; it is only formed

when these two gases are liberated in contact, as in the decay of animal and vegetable matter, where it is always present; the nitrogen being set free by the decomposition of the matter itself, and the hydrogen being evolved from the decomposition of water, which is always and under all circumstances necessary to produce the ultimate decay of matter.

Its price as an article of commerce will, it is feared, always prevent its use in a manufactured state, and indeed, if we only reflect on the immense quantities of this manure which are now wasted, and which might and ought to be saved, we shall be convinced that we never need apply to the manufactured article for a due supply of this important matter.

Ashes—Wood.—The benefit arising from the use of wood-ashes arises entirely from the potash they contain, which being dissolved by the first rain that falls after they are applied, dissolves the salt and carries it into the earth, there to be absorbed and assimilated as previously described.

Some kinds of wood (and in wood we should include all plants) yield in their lixiviation a much larger quantity of this salt than others,—thus the ashes of dried wormwood contain 30 per cent. of this salt, and are consequently very beneficial. The ashes of nettles, and generally the ashes of all plants which flourish on rubbish heaps, the ruins of old buildings, and in hedge rows are rich in these salts, as their luxuriant growth testifies to the abundant presence of the potash in the soil where they exist, and it would amply repay the agriculturist to collect such ve-

getables, merely for the sake of the potash they contain, to help to form the compost heap before mentioned.

The ashes of beech seem to possess a peculiar quality in addition to the salts of potash, viz. phosphates; and it is calculated that 100 lbs. of the lixiviated ashes of the beech, would yield as much phosphate as 400 lbs. of fresh human excrement, or enough to supply sufficient phosphoric acid for the production of 3820 lbs. of straw, or from 15 to 18,000 lbs. of corn.

Coal ashes—yield, on analysis, a small portion of sulphate of lime (gypsum,) charcoal and lime. The beneficial results arising from the use of these ashes are generally attributed to the sulphate of lime they contain; but as these results are so much greater, than are produced by an equal proportion of the sulphate, when applied in its pure state (that of gypsum,) the cause must be sought for in some other ingredient they contain; and with deference to those who have previously written on this subject, the greater portion of the good effect attending the use of coal ashes, may be attributed to the presence of the charcoal they contain. Elsewhere, the power possessed by charcoal of absorbing other gases, and again yielding them to the soil, will be alluded to, and it is to this power and the presence of carbon and nitrogen thus absorbed, that the benefit is supposed to be due. The lime which exists, independently of the gypsum, may also produce its effect, but the quantity contained in coal ashes is too small for it to be

the cause of the luxuriant effects which follow their use. It is here needless to repeat the effects produced by carbon and nitrogen on vegetation; the chapter devoted to each, will, it is hoped, fully explain their uses in connexion with the growth of plants.

Peat ashes, owe all their fertilizing property to the presence of 12 per cent. of gypsum, and the remarks made when speaking of that substance, (p. 103) will fully apply here. Rain is absolutely necessary, in all cases where gypsum is applied, to produce the desired effects; it acts by dissolving the ammonia absorbed by the gypsum, and which is thus conveyed into the soil, there to be absorbed and assimilated in the manner previously described.

The analysis of peat ashes yields 12 per cent. of sulphate of lime,—a sufficient quantity to account for the beneficial results which follow their use.

The other products of the analysis consist of

40 parts of carbonate of lime.

6 parts of salts of soda.

32 parts of silicious earth.

3 parts of oxide of iron.

7 loss.

Blubber, fish, oils, fat, &c.—The analysis of these substances yields upwards of 70 per cent. of carbon, on which all their fertilizing property depends. The first requisite, therefore, is so to mix them, that the carbon may become available when applied to the soil, and not, as in too many cases, so combined as to form either an insoluble compound, or one which is so readily found in nature as to render it quite

unnecessary for it to be manufactured in a more expensive way.

We would recommend, as the best means of preparing these substances for manures, that one or two gallons of either of the above oils should be mixed with five or six bushels of fresh coal ashes or charcoal, or a mixture of both. After laying a few days in this state fermentation would take place, the oil would be decomposed, and the carbon thus set free, would be at once absorbed by the charcoal or ashes, and as soon as ever this had taken place they should at once be used.

If to this mixture it were possible to add, as there is every reason to hope soon will be the case, some of the apatite or native phosphate of lime, we conceive that such a mixture would answer admirably for turnips; as it would furnish every requisite for the young plants and stimulate their growth, so as to render the effects of the fly, the black caterpillar, and the other enemies of this plant, quite abortive.

If these substances are mixed with lime, as is or has frequently hitherto been the case, decomposition speedily ensues, and the carbon resulting from such decomposition is at once absorbed by the lime to form carbonate of lime; a substance which it is not at all necessary thus to manufacture, seeing that it exists already abundantly in nature as chalk and limestone.

Fish, such as sprats, cockles, muscles, which in various parts of England are extensively used as a manure, are only valuable for the oil they contain, and being applied at once to the soil, the oil that is yielded during decom-

position is at once absorbed ; but as the quantity so applied is very small, the effects of a dressing of these fish seldom lasts beyond a year.

The price of oils, even the commonest that are to be had and during the cheapest years, (varying from 2s to 2s 6d per gallon) is such as to be a serious obstacle in the way of their use as a manure, the more so as other substances may be made available for the same purpose at a less cost.

Blubber, when it is to be had, is much lower in price than either of the oils ; but then its real value is about in the same proportion, as a great part of the blubber consists of earthy matter, which is comparatively useless. Still, compared with the cost of bones, the difference is in favour of the mixture of oil and ashes ; and a time may arrive when a sufficient supply of bones will be unattainable ; and, indeed, even now, their cost is a serious obstacle to their use : and it is, therefore, desirable in every way to be enabled to point out a substitute for their use.

Bones.—The remarks made when speaking of the phosphate of lime, (page 105) will explain the action of bones on vegetation. Their beneficial effects are attributed entirely to the presence of that substance, as whether new or old bones are made use of, the effects produced are the same.

It is a curious fact, and one which is characteristic of the energy with which all sources of commerce are pursued in this country, that the wild cattle existing in the extensive plains

of South America, are slaughtered often for no other purpose, than that their bones, ground into dust, may be exported for the supply of the turnip-fields of England.*

This branch of our trade, however, may have to be discontinued, as it is expected that a substitute will be found for the use of bones in apatite, or native phosphate of lime, a substance existing abundantly in Spain; a cargo of which is either arrived, or is expected to arrive in this country, when the experiment will, we have no doubt, be fairly tried. Even if a supply from this source should fail, there is little doubt but that phosphate of lime might be manufactured at a sufficiently low price to suit the purposes of agriculture.

Chalk.—See carbonate of lime, (p. 100.)

Charcoal.—This substance is destined for the future, to rank amongst the most valuable accessories that the farmer possesses; in its natural state it is indestructible, and no length of time produces the least effect on its substance, or impairs any of its original attributes; and this will be explained to be one of its most valuable properties to the agriculturist.

In its natural state it is black, perfectly insipid, and free from smell, insoluble in water, brittle, and easily pulverized; and when secured in close vessels, and the contact of the air entirely removed from it, it is unchanged by any degree of heat.

The peculiar property of charcoal, and the

* Daubeney.

only one that makes it useful in connexion with the subject of manures is, its powers of absorbing various gases in the pores of its structure, and subsequently yielding them to moisture.

It is proved beyond all doubt, that pure fresh burnt charcoal possesses the power of absorbing 90 times its volume of ammonial gas, and 35 times its volume of carbonic acid gas. It has the power also of absorbing the other gases, but it is needless to specify them here, as the two above quoted are those only which produce any effect in relation to agriculture. This property of charcoal is entirely a mechanical effect, and is not due to any chemical action resulting between the charcoal and the gas, as the gases so absorbed are readily given out when the charcoal is subjected to the heat of boiling water.

The densest and heaviest kinds of charcoal possess this capacity of absorption in the highest degree; and, consequently, charcoal prepared from boxwood is the best for this purpose: but this power in all cases is much diminished by reducing the charcoal to a state of powder; it should, therefore, when used for agricultural purposes, be just broken, so as to allow of its equal distribution over the surface of the soil. In this state it will absorb any gas with which it may come in contact; and if any manure has been applied containing ammonia in its free state, that is liable to pass off in a gaseous form, the charcoal will absorb it as it rises, and retain it until the first rain, when the gas will be dissolved by the water

and carried into the soil, there to be applied for the assimilation of plants, and the removal of the gas by the rain from the charcoal restores its original power of absorbing gas ; so that this substance, when applied to the soil, acts as a constant reservoir for these valuable gaseous substances, a property which neither time nor any circumstance can alter.

Even when, in the course of cultivation, the charcoal originally applied on the surface of the land is ploughed under the surface, even there it does not lose its power of absorbing the gases, but carries on its operations with undiminished energy.

Charcoal, thus applied, derives a supply of these gases from other sources than the soil, thus, if rain falls, and all rain generally contains a portion of ammonia, it is at once absorbed by the charcoal, or at least that portion which under other circumstances would be carried off during the evaporation of the moisture from the surface. It is to this peculiar property, that the whole benefit of charcoal as a manure is to be attributed ; it is, however, so extensively useful that a few of its applications are subjoined, in the belief that circumstances are daily occurring in which its application may be useful.

“Charcoal resists the putrefaction of animal substances. A piece of flesh, that is already tainted, may have its sweetness restored by rubbing it daily with powdered charcoal, and it may be preserved sweet for some considerable time by burying it in powdered charcoal ; which, however, it is necessary to renew daily.

“Putrid water is also restored by the use of this substance, and water may be kept unchanged at sea or elsewhere by perfectly charring the inner surface of the casks used to contain it.

“It produces also a remarkable effect, in destroying the taste, colour, and smell of many animal and vegetable substances. Common vinegar by being boiled in it is rendered perfectly limpid. Rum, and other ardent spirits, possessing a peculiar flavour and colour are deprived of both, by maceration with charcoal; and lastly, putrid animal matter and air, contaminated with offensive fumes, are completely deprived of their odour by contact with this substance.”—(*Henry's Chemistry.*)

Nothing can be added to this information to increase either its general or individual utility to the agriculturist, and it is hoped that the arguments now given, will not be entirely without their effect in inducing its use.

Dung—Farm-yard.—It would be altogether foreign to the purpose of this work to enter into a description of the various means that have been suggested from time to time for improving the management of the farm-yard with reference to the dung. It must suffice here if a general description is given of the contents of farm-yard manure, and of the best means for rendering such manure more valuable, by avoiding the loss that now generally ensues.

Farm-yard manure, then, in its general meaning, implies a mixture of vegetable matter and animal excrement in a state of decay. Vegetable matter, as we have previously seen, (p.

47,) yields in its decay carbon, which, provided it takes place under the ground or in or near situations where other plants are vegetating, is at once absorbed by them and assimilated in their growth; but if this decay is allowed to take place, as too frequently is the case, in situations where its carbon cannot be assimilated, then such carbon is entirely lost.

Animal excrement, urine, for instance, the principal ingredient in farm-yard manure, yields nitrogen, and both these substances, the nitrogen and carbon, are of primary importance in the growth of plants. It is, therefore, a question of considerable importance, how both these substances, arising from the decay of vegetable and animal matter, can be so produced, that all shall be absorbed and none be allowed to pass off in the gaseous state to the atmosphere. How, indeed, all may be saved and no part wasted? The query then is, how is this desirable arrangement to be produced? If straw, for instance, mixed with animal excrement were applied to the land in its fresh state, and then to be ploughed in, there can be no doubt but that all the carbon it may contain would be absorbed by the soil and none would be lost; but against this it may be fairly stated, that the time such straw would require for its decomposition, would render its effect in some measure useless, as the carbon yielded is principally necessary to plants in the early stage of their growth, when a rapid supply is necessary; and which, in this latter case, certainly would not be the case; but if, as is too frequently the case, the stable litter and other

farm-yard manure is put together in a heap and exposed to the weather, the moisture thus absorbed causes immediate decomposition, and the heap is observed to be reeking with steam during the whole day. This steam contains the most valuable portion of the heap, and the fermentation which this indicates should at once be stopped, as the ammonia arising from the decomposition of the urine is then volatilized (that is, flying off in the shape of vapour) and escaping at an immense sacrifice of real manure to the farmer. To prevent this, the manure heaps should always be kept dry, as moisture inevitably induces decomposition, and when once this has commenced it is difficult to stop its progress.

When such decomposition has commenced, the heaps should be spread open, so as in no part to be more than four inches thick, the decomposition would then, provided no moisture reached it, be stayed, and the manure might be kept in this state until wanted for use. Or, if this plan is not feasible, after having been spread out, some gypsum or charcoal fresh burnt should be spread in layers throughout the heap, and this would collect all the ammonia, which under other circumstances would be volatilized.

It cannot be too strongly impressed on all agriculturists, that by allowing their farm-yard manure to become rotten before it is used, they are suffering a severe loss of fertilizing matter, from the combined evaporation of the ammoniacal gases from its surface, and the washing away by means of the rain of the saline parti-

cles it once possessed, and that no heaps should be allowed to ferment and decompose until a few days prior to their application to the soil. The utility of allowing decomposition thus to commence, is that the ultimate decay of the manure is thereby hastened. Whereas if this decomposition had not so commenced before its application to the soil, a much longer time would be necessary for its decay therein.

Decomposition once having commenced in a dung heap, it is only to be arrested by being separated and kept dry, but when spread on the land, the natural moisture of the earth, independently of rain, would be sufficient for its renewal.

As far then as these observations have already extended, it seems desirable that farm-yard dung should be applied to the land, when decomposition has already decidedly commenced, but when it has not been carried so far as to have destroyed the vegetable structure. In this state we conceive it to be best adapted for promoting the growth of other plants; the moisture of the ground will facilitate its decay, and the supply of carbon will, from its continued decomposition, be uniform and abundant. And if no unnecessary time is allowed to elapse, from the time of its application to the soil to that of its being ploughed in, very little, if any, of its fertilizing properties will be lost.

The saline particles also which the refuse matter of all plants contain, will, when they are thus decomposed, be gradually dissolved in the soil, and will furnish their quota for the nutrition of other plants, and none will be wasted.

The animal matter too, such as the solid fæces, and the urine with which we assume the straw to be saturated, will equally be decomposed during the decay of the vegetable matter, and will afford a valuable supply of saline matter to the growing plant.

It may not be irrelevant to the subject now under consideration to note:—That the relative value of the manure of all animals, whether solid or liquid, depends in very great measure on the food they eat. If, for instance, the flock of sheep on a farm, live wholly on green food, such as grass and turnips, or on hay, it follows, as a matter of course, that the excrement can only consist of the refuse matter of such food not assimilated by the animal, and in the case now before us, as the food consists almost entirely of carbon, and a few earthy matters, so must the excrement also consist of carbon. But if, instead of these carbonaceous matters, the food of the sheep consists of corn or linseed cake, or other substances containing nitrogen, then will the excrement contain the nitrogen not necessary for the supply of the body; and arguing on the reasons we have before given, it is consequently assumed, that the excrement so voided, must be more valuable as a manure.

Hence, it is a question to be determined by agriculturists themselves, as to whether it would not be more to their advantage, to keep their flocks and cattle generally on more nutritious food, if only for the sake of the increased value of the manure. It may be thought perhaps presumptuous for an opinion on the subject to be offered here, but, notwithstanding,

we would respectfully beg to say, that in our estimation such a proceeding would amply repay the increased cost.

Bird's Dung.—The dung of all birds has always been esteemed as a valuable manure, and its excellence, in great measure, depends on the quantity of lime it contains.

In the excrement from poultry, this substance is not equally abundant as in that produced by the sea-fowl, which live entirely on animal matter.

The excrement of these latter birds, is found on many of the rocky and uninhabited isles of our northern coasts ; but the moist and humid atmosphere of this climate, combining with the heavy rains of winter to wash it away as soon as formed, has prevented an extensive deposit of this substance from taking place.

In the more genial climes, however, of the tropics, where the sun's rays have dried this excrement as soon as dropped, an inexhaustible supply exists ; and as its use as a manure has been recommended by various persons, from the time when Sir Humphrey Davy first called attention to it in 1804, to the present time, a cargo of this substance, known by the name of *Guano*, has this year (1841) been imported, with a view to its adoption here as a manure.

This substance is collected on the uninhabited and other islands of the South Sea, where sea-fowl in immense flocks have been congregated from time immemorial, and so abundant is it, that the whole soil, in some cases to the depth of many feet, is found to be

composed entirely of this substance. It has already been used as a manure on the continent of South America ; and there seems to be no doubt, but that its use will prove highly beneficial here, and at all events its merits will now be tested.

The following statement, affording all the information at present known relative to Guano, is extracted from one of the periodicals of the present day :—

“ Various opinions have been formed as to the origin of Guano, by some it is considered a mineral production, by others the excrement of sea-birds. At first sight, and without a careful examination, it is difficult to decide on this question. The immense quantities which have been removed from, and which are still to be found upon the islands and rocks off the coast of Peru, as well as upon the coast itself, its weight, the red colour of oxide of iron, and the difficulty of conceiving how any number of birds, however great, could have furnished so inexhaustible a supply,—these circumstances favour the idea of its being of mineral origin. But, on the other side, its physical and chemical characters oppose such a supposition, and would lead us to consider it as an animal production. The ammoniacal odour which it gives off, the existence of uric, phosphoric and oxalic acids, and of potass, its red colour (differing in intensity in proportion to the time it has been exposed to the air,) its identity of composition with the white Guano, which is produced daily, the circumstance of its being found only on the coast, and never in the inte-

rior, as well as the bones of these birds, which are used as cutting instruments by the Indians, having been found at some depth below the surface, and the fact of the white Guano assuming the red colour by time, as observed in the island of Torrecilla, are convincing proofs that the coloured Guano is an animal production.

“There are three varieties of Guano, the red, the dark gray, and the white. The first two are met with in the Isles of Chinca, near Pisco, at Iquique, and on the hill of Pica. The term “Guano of Iquique,” is sometimes used, from its having been first procured from the island of that name. This island is situated about 400 yards from the port of Iquique; it is about a half a mile long, and about 200 yards broad, and furnished large quantities of Guano for 25 years, when it became exhausted. The hill of Pica is very high, and is covered with Guano down to the water’s edge, while that side does not face the sea, is of sand and gravel. In this hill or rock, a silver mine was formerly worked, but no trace of Guano was found during the excavation. The adjoining hills on either side are of sand, which is carried by the winds, and covers up the Guano, to remove which the sand is first taken away, and deep excavations made, the Guano extending nearly a quarter of a league in length, and 300 yards in depth.*

“It is likewise found at St. Lobos, about three leagues to the south of Pica, but as the

* Query—300 yards from the shore inland?

anchorage hereabouts is dangerous, little business is done.

“The white Guano is considered the most valuable as being fresher and purer. It is found on nearly all the islands along the coast.

“These varieties of Guano have different prices; the red and dark gray are worth 2*s.* 3*d.* the cwt.; a higher price is given for the white, on account of its greater scarcity; it is sold in the Port of Mollendo at 3*s.* 6*d.* the cwt., and at times, as for instance during war, it has fetched as high a price as 12*s.*

“It has been observed, that in the Isles of Islay and Jesus, in those years when many birds have assembled here, from 400 to 500 cwt. have been taken away. Of late years there has been a diminution in the supply, from the birds having left these islands, owing to the following causes; the excessive heat of the late summers, the scarcity of food, and the number of vessels in port at one time, which by the noise occasioned, cannot fail to have driven them away; on which account, the proprietors of the Guano ground of Jesus, obtained schedules from the court of Spain, to prohibit vessels of war from touching at this port, since on their arrival all the birds immediately disappeared, to the prejudice of the proprietors; and since the opening of the port of Islay, the birds have nearly deserted the adjacent inlets.

“That careful and enterprising traveller, Baron Humboldt, after his voyage to Peru, sent a portion of Guano for analysis to the celebrated French chemists, Fourcroy and Vauquelin.

“The coloured Guano passes to the gray; has a rather strong ammoniacal odour, and is heavy; dissolves in acids with effervescence; a certain quantity being dissolved in water imports an odour similar to that of urine; its flavour is saltish and pungent; it gives precipitates with ammonia, the oxalate of potass, the nitrate of silver, with the subcarbonate and prussiate of potass. The solution being evaporated, cubic crystals of muriate of soda, and of muriate of ammonia are left, kept for some days it undergoes no alteration, and only acquires a strong smell and taste. The Guano being calcined, ammoniacal vapours are given off in abundance, leaving a very light carbon. Fourcroy and Vauquelin met with uric acid, in part saturated with ammonia and potass, phosphoric acid combined with the same basis and with lime, small quantities of the hydrochlorates of ammonia and potass, a small quantity of fatty matter, and of quartz and ferruginous sand. But in an analysis which the writer of this paper has recently made, he found it to contain a considerable quantity of the muriate of soda, of ammoniacal salts, and of iron. The white Guano is of the same composition, except that it is free from sand, has not so powerful a smell (from not having undergone spontaneous decomposition) is lighter, leaves more residue in the crucible, and contains a small proportion of iron and muriate of soda.

“The date of the discovery of the Guano, and of its introduction as a manure in Peruvian agriculture is unknown, though no doubt exists as to its great antiquity. In many parts of

America, where the soil is volcanic or sandy, no produce would be obtained without the Guano.

“It has been calculated that from 12,000 to 14,000 cwt. are annually sold in the port of Mollendo, for the use of the country around the city of Arequipa. In the province of Taracapa, and in the valleys of Tambo and Victor, the consumption should be something more; as wheat, all kinds of fruit trees, and plants, with the single exception of the sugar cane, are manured with the Guano, which is not the case with the district of Arequipa, where maize and the potatoe alone require it. In the district of Arequipa, three cwt. of the Guano is spread over an extent of 5000 square yards, but in Taracapa, and in the valleys of Tambo and Victor five cwt. are required.”

The analysis of Guano yields:

Phosphate of lime	.	.	.	30 $\frac{1}{2}$	parts.
Sulphates and muriates	.	.	.	3	“
Lythic acid	.	.	.	15	“
Ammonia	.	.	.	15	“
Other organic matter	.	.	.	36 $\frac{1}{2}$	“

It is recommended either to be sown or drilled with the seed, or as a top dressing, and in whatever way it is used, the subsequent application of a bushel of powdered charcoal is also recommended, as producing effects on the second crop quite equal to those on its first application.

It need hardly be stated here, that the use of the charcoal is to absorb the ammoniacal gases, which otherwise would escape and be wasted.

It is strongly recommended for wheat, barley, oats, turnips, clover, and hops. The quantity to be used per acre from 1 to 2 cwt. The price in November, 1841, is 26s. per cwt. in London.

Dogs' Dung.—When the dog is fed on flesh and bones only, the excrement yields upwards of 95 per cent. of phosphate of lime, and it is a question to be solved by experiment, whether the use of this manure, limited as the supply may be, would be beneficial. Reasoning from the contents we should say it would, but it might be improved by a mixture of charcoal, saturated with putrid urine, to furnish the ammoniacal salts.

Gas Liquor.—In the manufacture of gas, by submitting coal to distillation in iron retorts, besides the tar, a solution of carbonate of ammonia is produced in a liquid form, and is properly called ammoniacal liquor. In many cases this liquor is considered entirely as a refuse; in others, in the vicinity of manufactures, it is purchased by soap-boilers; and in a few cases it has been used as a manure; and there can be little doubt from the saline property that it contains, that by judicious treatment it may be rendered a very valuable fertilizer.

Carbonate of ammonia, as before noticed, is a valuable stimulant; but if the ammoniacal liquor is applied to the soil in this state, the ammonia would readily fly off in the state of vapour, and no benefit would be derived by the soil. To obviate this, it should first be converted into a sulphate of ammonia; that is, am-

monia combined with sulphuric acid. In this state the salt has entirely lost its volatile properties, whilst it retains its solubility, and is equally, if not more, fertilizing in its effects.

To convert this carbonate of ammonia, it is only necessary to add a sufficient quantity of sulphuric acid to the ammoniacal liquor, until all the effervescence caused by the acid has ceased. When this is effected, the carbonic acid gas has passed off, and the residue is an impure sulphate of ammonia. Or it may be made by mixing gypsum with the gas liquor, and allowing it to remain a few hours to decompose.

In its operation on plants, the sulphate of ammonia, when applied to the land, is dissolved by the first moisture, and carried into the soil, where it is absorbed by the roots of the plants; the ammonia is then decomposed, and the nitrogen it contains is assimilated in the way we have previously described (p. 62.)

It may be objected that this mode of proceeding is too expensive for general use; but as the sulphuric acid is one of the cheapest acids that exists; and as a pound (costing from 2*d* to 3*d*) of it will convert the carbonate contained in three gallons of gas liquor into a sulphate, and thereby furnish 30 oz. or nearly 2 lbs., of sulphate of ammonia, we think, indeed we feel assured, that the additional quantity of ammonia thus fixed in the soil would amply repay the outlay.

If the gas liquor is applied in its natural state, a portion certainly of the carbonate of ammonia it contains is absorbed by the earth;

but by far the larger portion would be carried off by evaporation with the watery parts; and therefore it is that its conversion into a sulphate of ammonia, before it is thus applied, is recommended. Or the field may be strewed with gypsum, and the gas liquor may then be sprinkled over it, when a natural decomposition will take place,—the carbonic acid gas of the ammonia would unite with the lime, and form carbonate of lime; and the sulphuric acid of the lime would unite with the ammonia and form sulphate of ammonia. Either of these plans is perfectly feasible, and we again repeat that a handsome return may be anticipated from a judicious outlay in either of these processes.

There is another refuse at gas-works, that may be used perhaps with advantage,—the lime through which the gas is passed for the purpose of purifying it; but, as it is exceedingly caustic in its effects, great care must be used. In the state in which it is sold at the gas-works, it exists as a hydro-sulphuret of lime; but on being exposed to the air, this property is lost, and it would eventually become a sulphate of lime (gypsum,) when it would of course become beneficial. But it is still a question, although there are some facts adduced to the contrary, whether on the whole it can be considered as beneficial in its caustic state.

Gypsum } See Lime.
Lime }

Liquid Manure.—and by this we mean the running of all stables, cow-sheds, and farm-

yards,—is too often allowed to be wasted, and, in too many cases, is felt to be a nuisance instead of being regarded as a most prolific fertilizer.

In the chapter on Urine we shall enter fully into its value as a manure. And as this liquid manure is composed principally of urine, largely diluted with water, and impregnated with other saline matters, which the rain has washed from decaying vegetables, we trust that its benefits will then be at once recognised.

Every farm-yard, every stable, every shed where cattle are kept, ought to be so arranged, as for the running of each to be preserved.

The liquid manure, thus obtained, should either be carried away and spread over the fields; or, better still, it may be allowed to become putrid, and then mixed in the compost heap to serve in the formation of nitre, (p. 83.)

In any case it ought not to be wasted. Its value as a fertilizer cannot be overrated; and it is hoped that England will soon follow the example of her continental neighbours in the use of this manure.

Night Soil.—The value of night soil as a manure, principally depends upon the presence of ammonia; and this ammonia is almost entirely derived from the urine with which night soil is always mixed.

Berzelius, in his analysis of the solid excrement, gives the proportion of nitrogen as varying from $1\frac{1}{2}$ to 5 per cent., and about 15 per cent. of ashes, principally composed of the phosphate of lime and magnesia. In all cases, however, night soils is richer in nitrogen than the excrement of any other animals.

That the use of this manure must be beneficial there can be, and is no doubt; but it is equally true, that in the way in which it is generally prepared, one-half or more of its valuable contents is lost: but even with all this loss, as it still is a very powerful manure, parties are generally satisfied with the result; although, properly treated, its fertilizing power might be increased five or six times.

The addition of lime, under any circumstances, is very prejudicial, as the ammonia is by this means at once liberated, the carbonic acid of the ammonia at once combining with the lime, and setting free the ammonia in a volatile state.

The beneficial results arising from soil so prepared, are attributed entirely to the phosphates which they still contain; for all the ammoniacal salts have been decomposed, and their ammonia expelled.

It is suggested, in the absence of any other information on the subject, that the best means of preparing the night soil without loss, would be to mix the mass, after it has been removed to some convenient spot, and allowed to putrefy, with the strongest sulphuric acid, until all effervescence, consequent on such mixture, had ceased. It may then be either left to dry of its own accord, or it may be mixed with good mould as free from lime as possible, or charcoal, and in this state freely exposed to the currents of air to dry it. But it should be protected from rain by a roof of some kind or other, as the moisture is doubly injurious, not only in

preventing its becoming dry, but by wasting away also the saline matter it contains.

Clarke's Dessicated Compost, Alexander's Chio Fou, Poitevin's Manure—are all, it is believed, the excrements solid and liquid, mixed together, dried in a somewhat similar manner; care being taken to fix the ammonia, and not allow it to escape in the state of vapour. The beneficial results arising from the use of these manures, is very decided, and the numerous proofs of their efficacy, should only act as a stimulus to all agriculturists, not to allow the waste, with respect to this manure, longer to continue.

It is abundant, cheap, and very fertilizing; and we know not that more can be said, to induce parties interested at once to adopt, not only its use, but its preparation. One considerable advantage, to be derived from its use as a manure is, that it contains no seeds, which when applied to the soil produce weeds; an inconvenience to which the excrement of horses and oxen is liable, from the circumstance of various kinds of seeds passing uninjured with the fæces, and which materially detracts from their value as a manure.

Potash.—See page 79.

Salt.—See page 86.

Salpetre.—See page 80.

Soda.—See page 85.

Soot has been extensively used as a manure for some years past, and we believe with unvarying success.

It owes its fertilizing power chiefly to the ammonia it contains, which being dissolved by

moisture and carried into the soil, produces the same effects as we have noticed when speaking of nitrogen.

A portion also of the beneficial effect of this application, may be attributed to the charcoal which partly composes it; and which, acting as an absorbent of the ammonia contained in the atmosphere may serve to increase its effect. Another portion may be attributed to the small quantity of saline matter it contains; but its principal use as a fertilizer is derived from the presence of ammonia.

Urine—"When it is considered," says Liebig, "that with every pint of urine, a pound of wheat might be produced; the indifference with which this liquid excrement has been regarded is quite incomprehensible."

We can here only join in expressing our surprise at such neglect; but we would at the same time fain hope that such neglect has arisen entirely from ignorance of its value, and in the zealous endeavours that are now making by agriculturists at large, and the zeal, energy, and ability that is now displayed, we may fairly anticipate a juster appreciation of this manure for the future.

That we do not overrate the value of this manure, may be proved from the following results of the analysis of 100 parts of wheat manured in different ways, and which places human urine in the very first place as to value.

We have before stated that the weight and value of wheat as an article of food, depends on the quantity of gluten it contains, and this fact admitted, no other argument is required

to convince us of the superiority of urine as a manure:*

	Gluten.	Starch.
100 parts of wheat manured with		
Human urine (dried) yielded	35.1	39.1
Bullock's blood (dried) . . .	34.2	41.3
Human fæces (dried) . . .	33.1	41.4
Sheep's dung . . .	22.9	42.8
Pigeon's dung . . .	12.2	63.2
Cow's dung . . .	12.0	63.3
Vegetable humus . . .	9.6	55.9
The same soil not manured . .	9.2	66.7

We have elsewhere (page 64) endeavoured to show, that all excrement partakes of the nature of the food; that if food, consisting almost wholly of nitrogen, is consumed, that such excrement will principally consist of the nitrogen not required to supply the waste of the body. That if food principally consists of substances in which carbon predominates, that the matter voided as excrement neither is not, nor cannot be so rich in nitrogen as in the preceding case: the rule holds good throughout all creation; and therefore, as man is a carnivorous animal, and lives in great measure on the flesh of animals, a substance almost entirely composed of nitrogen, human urine is much richer in this substance, nitrogen, than in animals living exclusively on vegetables. The analysis of these matters accordingly proves that human urine contains four times more fertilizing matter, than the urine of horses, cows, and sheep.

* Analysis of Hermbstoedt, quoted by Professor Daubeny.

In all the remarks then that follow, we must be considered as speaking of human urine; but the same arguments will apply to the urine of all animals, only in lesser proportion.

And it must be again repeated that the liquid excrement of all animals is infinitely to be preferred as a fertilizer to the solid excrement, the urine in all cases containing all the soluble salts which are thrown off from the body as waste matter; such as the ammoniacal salts, the phosphates of soda, potash, and magnesia, the substances which are now recognised as constituting the ingredients of all kinds of grain, and which are essential both to their growth and development, and for supplying the nutritive matter of the grain.

Berzelius gives, as the contents of 1000 parts of human urine in his elaborate analysis of the fluid,

Urea	30 parts
Lactate of ammonia and animal matter	17½ “
Uric acid	1 “
Sulphate of potash	3¾ “
Sulphate of soda	3¼ “
Phosphate of soda	3 “
Phosphate of ammonia	1½ “
Chloride of sodium	4½ “
Muriate of ammonia	1½ “
Phosphate of magnesia and lime	1 “
Water, mucus, and silex	933 “

“If, from the above analysis, we take the urea, lactate of ammonia, uric acid, the phosphate and muriate of ammonia, one per cent. of solid matter remains, consisting of ammoniacal salts, which must possess the same

action, whether they are brought on a field dissolved in water or urine." Hence the powerful influence of urine must consist in its ammoniacal salts. Now, when urine is allowed spontaneously to putrefy, one portion of the ammonia unites with the lactic acid to form lactate of ammonia, and another becomes volatile in the state of carbonate of ammonia.

The formation of this carbonate of ammonia entirely alters the state of the urine, rendering it an alkali, instead of an acid, which it is in its natural state, and this explains why putrefied urine is to be preferred as a manure to urine in its fresh state. Now the great object is to fix this carbonate of ammonia, or at all events the ammonia, in the soil.

If the urine is applied as a manure in this state, that is, with the lactate and carbonate of ammonia in solution, the latter salt, from being volatile, will evaporate with the watery parts of the fluid; and the loss which would accrue from this mode of using it, would amount to nearly one half of the weight of the urine employed. So that, if by any means we can fix the ammonia, that is, deprive it of its power to fly off with the evaporation of the watery parts of the urine, we shall increase its action twofold. This object may be effected in a variety of ways. If a field is strewed with fresh burnt gypsum (sulphate of lime) and then the putrefied urine be applied on its surface, the gypsum will absorb and decompose the carbonate of ammonia, and the carbonic acid gas thus disengaged, will unite with the lime to form carbonate of lime, and the sulphuric acid of the

lime will unite with the ammonia to form sulphate of ammonia, and this salt will remain in the soil and not be volatilized.

But a simpler way still is to mix the gypsum with the putrefied urine, and thus effect the double decomposition above described before distributing it on the soil.

The quantity necessary will of course depend on the quantity of carbonate of ammonia the urine may contain, and this not only varies with every stage of putrefaction, but depends also on the way in which it has been kept; and again, on the quality of the urine itself, no very definite quantity therefore can be named. But an easy way of knowing how much gypsum to put to a certain quantity of urine is to add it constantly at intervals of a few hours (taking care to stir the mixture well occasionally) as long as any volatile smell, similar to hartshorn, escapes, the absence of which will be a sure test that the ammonia has lost its volatile property, and has become, to use a chemical and expressive term, fixed.

Chloride of lime may be used for the like purpose, but being more expensive than the gypsum, it would not of course be resorted to.

Dried peat, tanner's bark, sawdust, turf and other similar substances, may be also used for this purpose, but the gypsum is decidedly preferable.

Sulphuric acid, the oil of vitriol of commerce, may also be advantageously used to fix this salt, and to do so nothing more is necessary than to mix a sufficient quantity of this acid with the putrefied urine until almost all

effervescence ceases, keeping it well stirred during the whole of the time, and taking care not to add an excess of acid. In this case the ammonia unites at once with the sulphuric acid to form the sulphate of ammonia; and the carbon, being disengaged, escapes in the state of a gas.

Other means might be used to effect the same results as we have here demonstrated; but it is needless to specify them, as those we have already detailed combine great facility as well as extreme cheapness.

Having thus specified the change that takes place in the state of urine; the best manner for converting the ammonia for the purposes of agriculture; we shall suggest the best means of practically using this manure on a farm.

The first thing necessary is to procure a supply of urine. But if due care is used to save all that is now wasted, no farm need be in want of it.

The supply being obtained, it should be placed in large casks or tanks, under cover, until the volatile smell of the ammonia indicates that decomposition has taken place. When this occurs, it may be either poured over a heap of compost, consisting of coal ashes, charcoal, or gypsum, in any proportions that are the most conveniently obtained, and then allowed to dry, by frequently turning the heap. Care being taken, that if any volatile smell occurs, during this process of drying, that more gypsum be at once added. The volatile ammonia will in this operation be absorbed by the gypsum, and converted into a sulphate of

ammonia, and other parts will be absorbed in the gaseous state by the charcoal and the ashes; but all will at once be yielded up to the first moisture, that may come in contact with the heap; and, therefore, it may be very properly classed amongst those fertilizers which act as a stimulus to the plant. We would, therefore, reasoning from analogy, suggest the use of this dried compost, as an excellent substitute for bones in the drill in sowing turnips. And we are farther confirmed in this opinion, from the fact, that new manure, the urate, only lately introduced, and which is presumed to be prepared somewhat in this way, has been found to answer admirably for the purpose intended. The addition, however, of a phosphate of lime, would increase its value in this respect, and render it undoubtedly more valuable than bones for this purpose.

Another compost heap, which would answer admirably for any purpose almost for which a manure can be required; that is, either as a stimulant for turnips, as a pabulum for wheat, or white crops—or, again, as a top dressing for either of the above, or for grass,—may be readily formed by mixing long stable litter, in which decay has already commenced, with the burnt ashes of vegetables or wood, in somewhat indefinite portions; taking care, however, that the litter should predominate, and then pouring over the heap daily a portion of the putrid urine, and stirring the mass well up together.

In this heap the ammonia of the urine would be decomposed; but the nitrogen, the

vivifying principle of the ammonia, would unite with the alkaline matter, the soda or potash of the burnt vegetable ashes, to form nitrate of potash or soda: the hydrogen, the other constituent of ammonia, being given off.

After what has already been said about the utility of these salts as fertilizers, it will be needless to add more here, than earnestly to recommend every agriculturist to adopt these simple means for the production of two manures, which in value to the farmer cannot be surpassed—both for the facility and economy with which they may be prepared, and which would by their fertilizing properties confer a benefit not only on the farmer, but on the community at large.

It may be urged as an objection, that in many localities, far distant from towns and cities, that this manure could not be obtained in sufficient quantities to supply the place of other substances more readily obtained. To this objection we would beg to suggest, that if ever a demand for this article exists, means will be taken to secure a supply; and, that in such a case as above supposed, the farmer's wagon would be enabled to load back from the towns or market where their produce must eventually be consumed, with this matter. And farther, they may commence with the supply that is always to be had to some extent on their own farms, and thus verify the results here predicted.

We will only add, that the urine of one man, taken at its lowest calculation, will pro-

duce in one year, a sufficient supply of nitrogen for the formation of 800 pounds of wheat, or 900 pounds of barley; a fact of sufficient importance, it is hoped, to induce a trial at least—and this trial fairly made, we have no doubt of the result.

Indeed, if all the human excrement, now worse than wasted, were applied to the purposes of agriculture, animal manure might be entirely dispensed with. But if we look at the subject on an extended scale, and see the thousands of acres now barely cultivated at all, but all of which only require manure to be applied to them, to enable them to yield abundant crops; and if we reflect on the benefits all must derive from such an increase to the real wealth of the country, as the cultivation of these lands would induce; and farther, that the increased means thus afforded, would as certainly induce an increased population, which again in their turn, acting fully up to this system, would again prove another source of wealth and strength to the community,—we may be enabled to estimate in some slight measure, the order and arrangement that exists in nature, for the support of all her creatures; and that it is the neglect of those means, which Providence in its wisdom, has placed at the service of man, and not any imperfection in the grand scheme of the creation, which has induced the impious belief by some, that a redundant population may be a curse instead of a blessing.

But to return more immediately to our subject. Enough has been said to show that

ample means exist for bringing all the waste lands gradually into cultivation, that we have the power, if we have the inclination, to do so. And the circumstances of an increased and rapidly increasing population, may compel a much more attentive consideration, than this subject has hitherto received, and one which eventually must lead to the benefit of all classes concerned.

So much for human urine. The urine of animals, as previously stated, from the nature of their food, contains much less nitrogen than that of man ; but is equally, and in many cases, much more rich in the saline properties it contains, such as the phosphates of magnesia, and the salts of potash and soda. They are, therefore, by no means to be neglected, and indeed all the remarks appended to the subject of human urine apply here only with lesser force. We would, however, recommend, that all stables, farm-yards, sheds, and other places where cattle are kept, should be so arranged, as for the urine to be saved, and applied in the manner we have before described.

Connected with this subject it may here be stated, that the strong volatile smell, which is almost overpowering, when entering a close confined stable, where many horses have been shut up for the night, arises entirely from the volatilizing of ammonia in the urine.

A very simple, and at the same time a very profitable way, of correcting this injurious atmosphere, is to strew the stable with gypsum, which would absorb the ammonia at once

as it is formed, and prevent the presence of this gas in the atmosphere. Such an arrangement, besides being profitable, as one source of accumulating ammonia, would also act beneficially on the horses so confined, as there can be no doubt, but that breathing such an atmosphere constantly for some hours together, induces a highly excited temperament, which leads to, or at all events very much increases, any local inflammatory action, and renders the cure of such a malady, both difficult and uncertain.

These remarks, however, do not go to the length of suggesting the use of gypsum as a cure for such a stable, it is only a means of absorbing the noxious principle and turning it to account, but ventilation, to a considerable extent, is the only cure and the best.

Of the relative value of human urine, when compared with other animal matters, it is calculated by Macaire, that 100 parts of human urine are equal, in their fertilizing power, to 1300 parts of the fresh dung of the horse, or 600 of those of the cow. Nothing more therefore can be said in favour of this manure; it must now be left to those who have the means of applying and testing its real value.

In speaking of nitrogen we have fully explained how ammonia acts as the pabulum of plants, but we will here again shortly repeat it.

Ammonia is composed of nitrogen and hydrogen. Now, when the ammonia, in a state of solution, is absorbed by the spongelets of the roots, decomposition takes place, the nitrogen is assimilated to form the gluten of the seed,

and the hydrogen either unites with carbon to form the essential or fixed oil of the plant, or is evaporated through the leaves as useless matter.

That such is the effect of ammonia or nitrogen, applied under any circumstance, in which the salt is soluble, can be easily demonstrated, by applying it to any crop, when it will speedily assume a dark green colour and luxuriant appearance, which is the peculiar effect of the nitrogen alone, and which is forcibly illustrated in the dark green circles, popularly called fairy rings, which exist on the downs, and which owe their dark colour entirely to the mushroom or fungus spawn, existing under the surface, and which spawn consists almost wholly of nitrogen, and communicates its property to the grass growing above.

The specific action of nitrogen also, by endowing the plant with greater energy, enables it to assimilate more carbon from the atmosphere, and thus the addition of this manure, which is in every respect an essential to plants, gives it a greater power of assimilating another substance of almost equal importance as itself.

In concluding our notice of this manure we can only repeat that the liquid and solid excrement of man used together, and prepared in the way we have described, forms, from its combination of ammonial salts with the phosphates of magnesia and soda, the most valuable compound that can be devised, and its extensive use, will confer a double benefit to the farmer and to the public, as well by the removal of matter which is now only considered as a nuisance, as by increasing the produce of the soil.

Woollen Rags.—Dr. Henry gives, as the analysis of 100 parts of wool:—

Carbon	.	.	.	55 parts.
Oxygen	.	.	.	29½ "
Hydrogen	.	.	.	3 "
Nitrogen	.	.	.	12½ "

with perhaps a trace of lime or some earthy matter.

Having thus given the analysis of wool, it can scarcely be necessary to observe, that the principal value of woollen rags as a manure depends on the 55 parts of carbon in every 100 that they contain, which by the slow decay of the structure of the substance is very gradually given out to the plant.

These woollen rags are most extensively used in Kent and Sussex, as a dressing for the hop grounds, where they produce a very striking effect. They have also been used on wheat with very good results, but we should consider them more adapted to beans and crops consisting of carbonaceous matter, than wheat.

Irrigation.—The last fertilizer we purpose noticing, is not the least valuable in the effects it produces. In the paragraph on Water (p. 69,) we have given its chemical formation and the changes it undergoes. Here the only subject for our consideration, is the effects produced by artificial irrigation, and the causes to which such effects are attributable.

It has been repeatedly tried to grow plants in pure distilled water, free from any admixture; but in every such case the plant has never

arrived at perfection: and the conclusion we would draw from this is, that water owes its fertilizing power as much to the foreign substances it contains, as to its moisture.

This being the case, we have only to reflect on the large quantity of soluble matter every river and every stream brings with it; almost all of which is deposited in its transit over the surface of an absorbent meadow, to be satisfied that this is one of the principal sources of the fertilizing effects of irrigation.

Much, however, depends upon the character of the water, the sources from which it springs, and the character of the soil through which it passes, its local position in or near to large towns, from which an incalculable supply of matter is always obtained.

In speaking of the kind of water most serviceable as a fertilizer, hard water is perhaps to be preferred, because it owes this character to the quantity of sulphate of lime (gypsum) it contains in solution, and which being deposited on the lands over which it passes, acts in the same way as gypsum applied as a top dressing.

Sir Humphrey Davy was of opinion, that the temperature of water exerted a considerable influence on the growth and development of vegetation—and there is no doubt but that this has its effect—but it is now supposed to be subordinate in its effects to those produced by the causes already stated, and by the oxidizement of various matters contained in the soil; and which being thus effected by the continual

passage of the water, are thereby rendered in a fit state to act as the pabulum of the grass, by furnishing an increased supply of carbon.

That the fertilizing effects of irrigation are due to the presence of something more than mere water, may be proved from the fact, that stagnant water produces the very reverse of a running stream, which is quite contrary to what should be the case, was water the only requisite for a luxuriant vegetation.

CONCLUSION.

WE have thus completed the task originally contemplated, we have traced the organization of the vegetable structure and the functions allotted to each part of the plant, from the period of the germ's first appearance to the completion of its allotted purpose—the ripening of the seed.

The subject of the composition of the soil has also come under our notice, and we have endeavoured to point out the conditions necessary to be observed, for the perfection of the crops growing on its surface; and, lastly, the matter composing the structure of the plant itself, the sources from which it is derived, and the manner in which it is assimilated, have been fully entered into, leaving, it is hoped, little in the present state of our knowledge on this subject to be desired. This with the specific action of the various manures, completes the subject, which it is hoped will be found practically useful to those employed in the cultivation of the soil.

We know not that more cogent arguments for the union of Chemistry with Agriculture can be adduced, than already exist in the stimulus all parties possess for advancing their individual interests; but of this we may feel assured, that as the end and object of all knowledge, in connexion with this subject, is to increase the produce of the earth, so those who will not avail themselves of the assistance chemistry affords, will be left behind in the struggle which is going on; and farther, those who do rely on science for an elucidation of the hitherto mysterious operations of nature, will not only derive a direct and immediate benefit from the application of chemistry to agriculture, but they will also proceed with less difficulty, from being assured that the laws of nature are uniform in their operation, and that a certain cause will always induce a certain result.

THE END.

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