THE

ELEMENTS OF AGRICULTURE:

A Book for Young Farmers.

BY

GEO. E. WARING, Jr.,

AUTHOR OF "DRAINING FOR PROFIT AND DRAINING FOR HEALTH,"
FORMERLY AGRICULTURAL ENGINEER OF THE CENTRAL
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The effort to extend the dominion of man over nature is the most healthy and most noble of all ambitions.—Bacon.

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The first edition of this book was written in 1853, when the writer was full of the enthusiasm that comes with the first years of study; when a very elementary knowledge of the subjects of which it treats made the whole plan of vegetation, cultivation, and manuring seem easy and simple. In some instances, rather vague fancies were presented as sound theories; and the perplexing uncertainties which beset the path of the more thorough student were ignored—because unknown.

The observation and experience of the intervening years have sadly clouded some of these fancies, and the veil which hangs about the true theories of agriculture has grown harder to penetrate,—the difficulties in the way of precise knowledge have not lessened with closer acquaintance.

Notwithstanding its faults, the book received a very cordial welcome at the hands of the public,—more because such a book was much needed, than because of its real value, and it ought, long ago, to have been rewritten.

The present edition has been carefully revised, and it is believed that its doctrines are such as the positive teachings of chemistry, and the more enlightened practice of farming, will justify; still, it is offered with more hesitation than was its predecessor, and it is only offered at all because there exists a sad deficiency in this department of our agricultural literature.

The place that it is intended to fill is occupied by no other work. It is not an agricultural chemistry, nor is it a hand-book of the processes of every-day farming;—only an attempt to translate into common language, for the use of every-day farmers, that which science has discovered and has told in its own necessarily technical terms, and which practical experience has proven to be of practical value.

The facts which it sets forth lie at the very ground-work of the art of farming, and they are necessary to the *business education* of every farmer. On the universal importance of these facts the book must depend for its success; and for their sake,—not because of its own merit,—it is confidently offered to the young farmers of America, as being worthy of their most careful study.

Ogden Farm,
Newport, R. I., 1868.

SECTION FIRST.

THE PLANT

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THE PLANT.

CHAPTER I.

INTRODUCTION.

The object of cultivating the soil is to raise from a crop of *plants*. In order to cultivate with economy we must *raise the largest possible quantity with the least expense, and without permanent injury to the soil.*

Before this can be done we must study the character of plants, and learn their exact composition. They are not *created* by a mysterious power, they are merely made up of matters already in existence. They take up water containing food and other matters, and discharge from their roots, or their leaves, or deposit within their pores, those substances that are not required for their growth. It is necessary for us to know what kind of matter is required as food for the plant, and whence it is to be obtained; this we can learn only through such means as shall separate the elements of which plants are composed;

in other words, we must *take them apart*, and examine the different pieces of which they are made up.

If we burn any vegetable substance it disappears, except a small quantity of earthy matter, which constitutes the ashes. In this way we make the first division between the two distinct classes of the constituents of plants. One portion escapes into the atmosphere, and the other remains as a disorganized earthy substance.

That part which burns away during combustion we will call *atmospheric* matter, because it was derived by the plant from the air; the ashes which remain we will call *earthy* matter, because they were derived from the soil. The atmospheric matter has become air, and it was originally obtained from air. The earthy matter has become earth, and was obtained from the soil.

This is the first step toward a knowledge of agricultural chemistry. The next will be to examine each of these two different classes of matter, that we may learn precisely of what they consist. Then we must inquire where these substances are found, how they are taken up by the plant, and how we can best supply such as nature, unaided, does not always furnish. This knowledge does not require that farmers become chemists. All that is required is, that they should know enough of chemistry to understand, so far as the present state of knowledge makes it possible, the nature of the materials of which their crops are composed, and how those materials are to be used to the best advantage.

The elements of this knowledge may be easily acquired, and should be possessed by every person, old or young, whether actually engaged in the cultivation of the soil or not. All are dependent on vegetable productions, not only for food, but for every comfort and convenience of life. It is the object of this book to teach young farmers the first principles of agriculture: and while it does not contain all that is absolutely necessary to an understanding of the practical operations of cultivation, its teachings are such as the writer found, in his early studies, to be most necessary as a groundwork for future study and thought and most useful in practice.

We will first examine the *atmospheric* part of plants, or that which is driven away during combustion or burning. This matter, though apparently lost, is only changed in form.

It consists of one solid substance, *carbon* (or charcoal), and three gases, *oxygen*, *hydrogen* and *nitrogen*. These four kinds of matter constitute nearly the whole of most plants, the ashes forming sometimes less than one part in one hundred of their dry weight.

When wood is burned in a close vessel, or otherwise protected from the air, its carbon becomes charcoal. All plants contain this substance, it forming usually about one-half of their dry weight. The remainder of their atmospheric part consists of the three gases named above. By the word gas, we mean *aeriform* matter. Oxygen, hydrogen and nitrogen, when pure, always exist in the form of air. Oxygen has the power of uniting with many substances, forming compounds which are different from either of their constituents alone. Thus: oxygen unites with *iron* and forms oxide of iron or *iron-rust*, which does not resemble the grey metallic iron nor the gas oxygen; oxygen unites with carbon and forms carbonic acid, which is an invisible gas, but not at all like pure oxygen; oxygen combines with hydrogen and forms water. All water, ice, steam, etc., are composed of these two gases. We know this because we can artificially decompose, or separate, all water, and obtain as a result simply oxygen and hydrogen, or we can combine these two gases and thus form pure water; oxygen combines with nitrogen and forms nitric acid. These chemical changes and combinations take place only under certain circumstances, which, so far as they affect our subject, will be considered in the following pages.

As the atmospheric elements of plants are obtained from matters existing in the atmosphere which surrounds our globe, we will examine its condition.

CHAPTER II.

THE ATMOSPHERE AND ITS CARBON.

Atmospheric air is composed of oxygen and nitrogen Their proportions are, one part of oxygen to four parts of nitrogen. Oxygen is the active agent in the combustion, decay, and decomposition of organized bodies (those which have possessed animal or vegetable life, that is, organic matter), and others,—also, in the breathing of animals. Experiments have proved that if the atmosphere consisted of pure oxygen every thing would be speedily destroyed, as the processes of combustion and decay would be greatly quickened, and animals would be so stimulated that they would soon die. One use of the nitrogen in the air is to *dilute* the oxygen, and thus reduce the intensity of its effect.

Besides these two great elements, the atmosphere contains certain impurities which are of great importance to vegetable growth; these are, *carbonic acid*, *water*, *ammonia*, *etc.*

CARBONIC ACID.

Carbonic acid is, in all probability, the only source of the carbon of plants, and consequently supplies more material to vegetation than any other single sort of food. It is a gas, and is not, under natural circumstances, perceptible to our senses. It constitutes about $\frac{1}{2500}$ of the atmosphere, and is found in combination with many substances in nature. Marble, limestone and chalk, are carbonate of lime, or carbonic acid and lime in combination; and carbonate of magnesia is a compound of carbonic acid and magnesia. This gas exists in combination with many other mineral substances, and it is contained in all water not recently boiled. Its supply, though small, is sufficient for the purposes of vegetation. It enters the plant in two ways—through the roots in the water which goes to form the sap, and at the leaves, which absorb it from the air in the form of gas. The leaf of the plant seems to have three offices: absorbing carbonic acid from the atmosphere—assisting in the chemical preparation of the sap—and evaporating its water. If we examine leaves with a microscope we shall find that some have as many as 170,000 openings, or mouths, in a square inch; others have a much less number. Probably the pores on the under side of the leaf generally absorb the carbonic acid. This absorptive power is illustrated when we apply the lower side of a cabbage leaf to a wound, as it draws strongly—the other side of the leaf has not an equal effect. Young green shoots and sprouts doubtless have the power of absorbing and decomposing carbonic acid.

The roots of plants, by their absorbent surfaces, or through the spongioles at the ends of their roots, absorb from the soil water, which contains carbonic acid and other substances required for their nutrition. How large a proportion of the carbonic acid is absorbed in this manner is not definitely known. It probably depends on various circumstances, but is, no doubt, always important.

Carbonic acid, it will be recollected, consists of *carbon and oxygen*, while it supplies only *carbon* to the plant. It is therefore necessary that it be divided, or decomposed, and that the carbon be retained while the oxygen is sent off again into the atmosphere, to perform again its office of uniting with carbon. This decomposition takes place in the *green* parts of plants and only under the influence of daylight. It is not necessary that the sun shine directly on the leaf or green shoot, but this causes a *more rapid* decomposition of carbonic acid, and consequently we find that plants which are well exposed to the sun's rays make the most rapid growth.

The fact that light is essential to vegetation explains the conditions of different latitudes, which, so far as the assimilation of carbon is concerned, are much the same. At the Equator the days are but about twelve hours long. Still, as the growth of plants is extended over nearly or quite the whole year, the duration of daylight is sufficient for the requirements of a luxuriant vegetation. At the Poles, on the contrary, the summer is but two or three months long; here, however, it is daylight all summer, and plants from continual growth develop themselves in that short time.

It will be recollected that carbonic acid constitutes but about $\frac{1}{2500}$ of the air, yet, although about one-half of all the vegetable matter in the world is derived from this source, as well as all of the carbon required by the growth of plants, its proportion in the atmosphere is constantly about the same. In order that we may understand this, it becomes necessary for us to consider the means by which it is formed. In the act of burning, carbon unites with oxygen, and always when bodies containing carbon are burnt *with the presence of atmospheric air*, the oxygen of that air unites with the carbon, and forms carbonic acid. The same occurs when bodies containing carbon *decay*, as this is simply a slower *burning* and produces the same results. In the breathing of animals the carbon of the blood combines with the oxygen of the air drawn into the lungs, and their breath, when thrown out, always contains carbonic acid. From this we see that the reproduction of this gas is the direct effect of the destruction of all organized bodies, whether by fire, decay, or consumption by animals.

Furnaces are its wholesale manufactories. Every cottage fire is continually producing a new supply, and the blue smoke issuing from the cottage-chimney, contains materials for making food for the cottager's tables and new faggots for his fire. The wick of every burning lamp draws up the carbon of the oil to be made into carbonic acid in the flame. All matters in process of combustion, decay, fermentation, or putrefaction, are returning to the atmosphere those constituents, which they obtained from it. Every living animal, even to the smallest insect, by respiration, spends its life in the production of this material, so necessary to the growth of plants, and at death gives up its body in part for such formation by decay.

Thus we see that there is a continual change from the carbon of plants to air, and from air back to plants, or through them to animals. As each dollar in gold that is received into a country permanently increases its amount of circulating medium, and each dollar sent out permanently decreases it until returned, so the carbonic acid sent into the atmosphere by burning, decay, or respiration, becomes a permanent stock of constantly changeable material, until it shall be locked up for a time, as in a house which may last for centuries, or in an oak tree which may stand for thousands of years. Still, when these decay, the carbon which they contain must be again resolved into carbonic acid.

The coal-beds of Pennsylvania are mines of carbon once abstracted from the atmosphere by plants. In these coal-beds there are found various forms of organized matter. These existed as living things before the great floods, and it is the theory of some geologists that at the breaking away of the barriers of the immense lakes, of which our present lakes were merely the deep holes in their beds, they were washed away and deposited in masses so great as to take fire from their chemical changes. It is by many supposed that this fire acting throughout the entire mass (without the presence of air *to supply oxygen* except on the surface) caused it to become melted carbon, and to flow around those bodies which still retain their shapes, changing them to coal without destroying their structures. This coal, so long as it retains its present form, is lost to the vegetable kingdom, and each ton that is burned, by being changed into carbonic acid, adds to the ability of the atmosphere to support vegetation.

Thus we see that, in the provisions of nature, carbon, the grand basis, on which all organized matter is founded, is never permanent in any of its forms.

Oxygen is the carrier which enables it to change its condition. For instance, let us suppose that we have a certain quantity of charcoal; this is nearly pure carbon. We ignite it, and it unites with the oxygen of the air, becomes carbonic acid, and floats away into the atmosphere. The wind carries it through a forest, and the leaves of the trees with their millions of mouths drink it in. By the assistance of light it is decomposed, the oxygen is sent off to make more carbonic acid, and the carbon is retained to form a part of the tree. So long as that tree exists in the form of wood, the carbon will remain unaltered, but when the wood decays, or is burned, it immediately takes the form of carbonic acid, and mingles with the atmosphere ready to be again taken up by plants, and have its carbon deposited in the form of vegetable matter.

The blood of animals contains carbon derived from their food. This unites with the oxygen of the air drawn into the lungs and forms carbonic acid. Without this process, animals could not live. Thus, while by the natural operation of breathing, they make carbonic acid for the uses of the vegetable world, plants, in taking up carbon, throw off oxygen to keep up the life of animals. There is perhaps no way in which we can better illustrate the changes of form in carbon than by describing a simple experiment.

Take a glass tube filled with oxygen gas, and put in it a lump of charcoal, cork the ends of the tube tightly, and pass through the corks the wires of an electrical battery. By passing a stream of electrical fluid over the charcoal it may be ignited, when it will burn with great brilliancy. In burning it unites with the oxygen forming carbonic acid, and disappears. It is no more lost, however, than is the carbon of wood which is burned in a stove; although invisible, it is still in the tube, and may be detected by careful weighing. A more satisfactory proof of its presence may be obtained by *decomposing* the carbonic acid by drawing the wires a short distance apart, and giving a *spark* of electricity. This immediately separates the oxygen from the carbon, which forms a dense black smoke in the tube. By pushing the corks together we may obtain a wafer of charcoal of the same weight as the piece introduced. In this experiment we have changed carbon from its solid form to an invisible gas and back again to a solid, thus fully representing the continual changes of this substance in the destruction of organic matter and the growth of plants.

CHAPTER III.

HYDROGEN, OXYGEN AND NITROGEN.

HYDROGEN AND OXYGEN.

Let us now consider the three gases, *hydrogen*, *oxygen*, and *nitrogen*, which constitute the remainder of the atmospheric part of plants.

Water is composed of hydrogen and oxygen, and, if analyzed, yields simply these two gases. Plants perform such analysis, and in this way are able to obtain a sufficient supply of these materials, as their sap is composed chiefly of water. Whenever vegetable matter is destroyed by burning, decay, or otherwise, its hydrogen and oxygen unite and form water, which usually escapes in the form of an invisible vapor. The atmosphere of course contains greater or less quantities of watery vapor arising from this cause and from the evaporation of liquid water. This vapor condenses, forming rains, etc.

Hydrogen and oxygen are never taken into consideration in manuring lands, as they are so readily obtained from the water constituting the sap of the plant, and consequently they need not occupy our attention in this book.

NITROGEN.

Nitrogen, the only remaining *atmospheric* constituent of vegetable matter, is for many reasons worthy of close attention.

1. It is necessary to the growth and perfection of all cultivated plants.

2. It is necessary to the formation of all animal substances.

3. It is often deficient in the soil.

4. It is liable to be easily lost from manures.

Athough about four-fifths of atmospheric air are pure nitrogen, it is almost certain that plants get no nutriment directly from this source. It is all obtained from some of its compounds, chiefly from the one called ammonia. Nitric acid is also a source from which plants may obtain nitrogen, though, to the farmer, it is of less importance than ammonia.

AMMONIA.

Ammonia is composed of nitrogen and hydrogen. It has a pungent smell and is familiarly known as *hartshorn*. The same odor is often perceptible around stables and other places where animal matter is decomposing. All animal muscle, certain parts of plants and other organized substances, consist of compounds containing nitrogen. When these compounds undergo combustion, or are in any manner decomposed, the nitrogen which they contain unites with hydrogen, and forms ammonia. In consequence of this the atmosphere always contains more or less of this gas, arising from the decay and combustion which are continually going on all over the world.

This ammonia in the atmosphere and that which is contained in the soil (derived from the decomposition of organic matters within it) is the capital stock to which all plants, not artificially manured, must look for their supply of nitrogen. As they take up ammonia chiefly if not entirely through their roots, we must discover some means by which it may be conveyed from the atmosphere to the soil.

Water may be made to absorb many times its bulk of this gas, and water with which it comes in contact will immediately take it up. Spirits of hartshorn is merely water through which ammonia has been passed until it is saturated.* This power of water has a direct application to agriculture, because the water constituting rains, dews, etc., absorbs the ammonia which the decomposition of nitrogenous matter had sent into the atmosphere, and we find that all rain, snow, and dew, contain ammonia. This fact may be chemically proved in various ways, and is perceptible in the common operations of nature. Every person must have noticed that when a summer's shower falls on the plants in a flower garden, they commence their growth with fresh vigor, while the blossoms become larger and more richly colored. This effect cannot be produced by watering with spring water, unless it be previously mixed with ammonia, in which case the result will be the same.

Although ammonia is a gas and pervades the atmosphere, few, if any, plants can take it up, as they do carbonic acid, through their leaves. It must all enter through the roots in solution in the water which goes to form the sap. Although the amount received from the atmosphere is of great importance, there are few cases where artificial applications are not beneficial. The value of farm-yard and other animal manures, depends largely on the ammonia which they yield on decomposition. This

* By *saturated*, we mean that it contains all that it is capable of holding.

subject, also the means for retaining in the soil the ammoniacal parts of fertilizing matters, will be fully considered in the section on manures.

After ammonia has entered the plant it may be decomposed, its hydrogen separated from it, and its nitrogen retained to answer the purposes of growth. The changes which nitrogen undergoes, from plants to animals, or, by decomposition, to the form of ammonia in the atmosphere, are as varied as those of carbon and the constituents of water. The same little atom of nitrogen may one year form a part of a plant, and the next become a constituent of an animal, or, with the decomposed dead animal, may form a part of the soil. If the animal should fall into the sea it may become food for fishes, and our atom of nitrogen may form a part of a fish. That fish may be eaten by a larger one, or at death may become food for the whale, through the marine insect on which it feeds. After the abstraction of the oil from the whale, the nitrogen may, by the putrefaction of his remains, be united to hydrogen, form ammonia, and escape into the atmosphere. From here it may be brought to the soil by rains, and enter into the composition of a plant, from which, could its parts speak as it grows in our garden, it could tell us a wonderful tale of travels, and assure us that, after wandering about in all sorts of places, it had returned to us, the same little atom of nitrogen which we had owned twenty years before, and which for thousands of years had been continually going through its changes.

Liebig says: "All the nitrogen of plants and of animals is derived from the air. Every fireplace where coals are burned, the numerous furnaces and chimneys of the manufacturing towns and districts, of locomotive engines and steamboats, all the smelting furnaces of the iron-works—all these are so many forms of distillatory apparatus which enrich the atmosphere with the nitrogenized food of a vegetable world, belonging to a period long past.

"We can form some idea of the quantities of ammonia thus poured into the atmosphere, if we consider that in numerous gas-works many tons of ammoniacal salts are annually obtained from the coals distilled for gas." *

The same is true of any of the atmospheric or earthy constituents of plants. They are performing their natural offices, or are lying in the earth, or floating in the atmosphere, ready to be lent to any of their legitimate uses, sure again to be returned to their starting point.

Thus no atom of matter is ever lost. It may change its place, but it remains for ever as a part of the capital of nature.

* Journal of the Royal Agricultural Society, vol. xvii., p. 289.

CHAPTER IV.

EARTHY MATTER.

We will now examine the ashes left after burning vegetable substances. This is earthy matter; and it is obtained from the soil. Atmospheric matter, although forming so large a part of the plant, we have seen to consist of four different substances. The earthy portion, on the contrary, although forming so small a part, consists of no less than *nine* or *ten* different kinds of matter. These we will consider in order. In their relations to agriculture they may be divided into *three* classes—*alkalies*, *acids*, and *neutrals*.*

Alkalies and acids are of opposite properties, and when brought together they unite and neutralize each other, forming compounds which are neither alkaline nor acid in their character. Thus, carbonic acid (a gas) unites with lime—a burning, caustic substance—and forms marble, which is a hard, tasteless stone. Alkalies and acids are characterized by their tendency to unite with each other, and the compounds thus formed have many and various properties, so that the characters of the constituents give no indication of the character of the compound. For instance, lime causes the gases of animal manure

* This classification is not strictly scientific, but it is one which the learner will find it well to adopt. These bodies are called neutrals because they have a less decided alkaline or acid character than the other.

to escape, while sulphate of lime (a compound of sulphuric acid and lime) produces an opposite effect, and prevents their escape.

The substances coming under the signification of neutrals, are less affected by the laws of combination, still they do combine with other substances, and some of the resultant compounds are of great importance to agriculture.

ALKALIES.

The alkalies which are found in the ashes of plants are four in number; they are *potash*, *soda*, *lime*, and *magnesia*.

POTASH.

When we pour water over wood ashes it dissolves the *potash* which they contain, and carries it away in solution. This solution is called *ley*, and if it be boiled to dryness it leaves a solid substance which is chiefly pure potash. Potash left exposed to the air absorbs carbonic acid and becomes carbonate of potash or *pearlash;* if another atom of carbonic acid be added, it becomes super-carbonate of potash, or *salæratus.* Potash has many uses in agriculture.

1. It forms a constituent of nearly all plants.

2. It unites with silicic acid and forms a compound which water can dissolve and carry into the roots of plants; thus supplying them with an ingredient which gives them much of their strength.

3. It is a strong agent in the decomposition of vegetable matter, and is thus of much importance in preparing manures.

4. It roughens the smooth round particles of sandy soils, and prevents their compacting, as they are often liable to do.

5. It is also of use in killing certain kinds of insects, and, when externally applied, in smoothing the bark of fruit trees.

The source from which this and the other earthy matters required are to be obtained, will be more fully considered in the section on manures.

SODA.

Soda, one of the alkalies contained in the ashes of plants, is very much the same as potash in its agricultural character and uses. Soda exists very largely in nature, as it forms an important part of common salt, whether in the ocean or in those inland deposits known as rock salt. When combined with sulphuric acid it forms sulphate of soda or *Glauber's salts*. In combination with carbonic acid, as carbonate of soda, it forms the common washing soda of the shops.

LIME.

Lime is in many ways important in agriculture :

1. It is a constituent of plants and animals.

2. It assists in the decomposition of vegetable matter in the soil as well as of its minerals.

3. It corrects the acidity* of sour soils.

* Sourness.

4. Combined with chlorine or sulphuric acid as chloride or sulphate of lime it is a good fixer of fertilizing gases.

In nature it exists most largely in the form of carbonate of lime; that is, as marble, limestone, and chalk—these all being of the same composition. In manufacturing caustic (or quick) lime, the carbonate of lime is burned in a kiln; by this means the carbonic acid is driven off into the atmosphere and the lime remains in a pure or caustic state.

MAGNESIA.

Magnesia is the remaining alkali of vegetable ashes. It is well known as a medicine, both in the form of calcined magnesia, and, when mixed with sulphuric acid, as epsom salts.

Although magnesia is a necessary constituent of plants, it is not an element of which fertile soils are likely to become exhausted, and it does not receive attention in special manuring; the amount returned to the soil in farm-yard manure, and that supplied by the decay of roots, being sufficient for the growth of the most luxuriant crops.

ACIDS.

PHOSPHORIC ACID.

Phosphoric acid is a constituent of the ashes of plants which is of the greatest value to the farmer; it is composed of phosphorus and oxygen. Being an acid, this substance has the power of combining with any of the alkalies. Its most important compound is formed with lime.

Phosphate of lime forms about 65 per cent. of the dry weight of the bones of all animals, and it is all derived from the soil through the medium of plants. As plants are intended as food for animals, nature has provided that they shall not attain their perfection without taking up a supply of phosphate of lime as well as of their other earthy ingredients; consequently, there are many soils which will not produce good crops, simply because they are deficient in phosphate of lime. It is one of the most important ingredients of manures, and its value is dependent on certain conditions which will be hereafter explained.

Another use of phosphoric acid in the plant is to supply it with the small amount of *phosphorus*, which seems to be required in the formation of the seed.

SULPHURIC ACID.

Sulphuric acid is important to vegetation, and its addition to the soil often renders it more fertile. It is composed of sulphur and oxygen, and is made for manufacturing purposes, by burning sulphur. With lime it forms *sulphate of lime*, which is gypsum or "plaster." In this form it is often found in nature, and is most extensively used in agriculture. The methods for supplying sulphuric acid will be described hereafter. It gives to the plant a small portion of *sulphur*, which is necessary to the formation of some of its parts.

SILICIC ACID, OR SILICA.

This is common sand. In its pure state it cannot be dissolved and plants can make no use of it. It unites with the alkalies and forms compounds, such as *silicate of potash*, *silicate of soda*, *etc.*, which are soluble in water, and therefore available to plants. If we roughen a corn stalk with sand-paper we may sharpen a knife upon it. This is owing to the hard particles of silica which its outer parts contain. Window glass is silicate of potash, rendered insoluble by additions of arsenic and litharge.

Liebig tells us that there was discovered, between Manheim and Heidelberg in Germany, a mass of melted glass where a hay-stack had been struck by lightning. They supposed it to be a meteor, but chemical analysis showed that it was only the compound of silicic acid and potash which served to strengthen the grass.

There is always *enough* silicic acid in the soil, but it is often necessary to add an alkali to render it soluble and available. When grain, etc., lodge or fall down from their own weight, it is probable that they are unable to obtain from the soil a sufficient supply of the soluble silicates to support their rapid growth.

NEUTRALS.

CHLORINE.

Chlorine is an important ingredient of vegetable ashes. It is not found alone in nature, but is always in combination with other substances. Its most important compound is with sodium, forming *chloride of sodium* (or common salt). Sodium is the base of soda, and common salt is usually the cheapest source from which to obtain both soda and chlorine. Chlorine unites with lime in the formation of *chloride of lime*, which is much used to absorb or destroy the unpleasant odors of decaying matters, and in this character it is of use in the treatment of manures.

OXIDE OF IRON.

Oxide of iron, one of the constituents of ashes, is common iron rust. *Iron* itself is naturally of a greyish color, but when exposed to the atmosphere, it readily absorbs oxygen and forms a reddish compound. It is in this form that it usually exists in the soil, and many soils as well as the red sandstones are colored by it. It is seldom, if ever, necessary to apply this as a manure, there being usually enough of it in the soil.

This red oxide of iron, of which we have been speaking, is called by chemists the *peroxide.* There is another compound which contains less oxygen than this, and is called the *protoxide of iron*, which is poisonous to plants. When it exists in the soil it is necessary to use such means of cultivation as shall expose it to the atmosphere and allow it to take up more oxygen and become the peroxide. The black scales which fly from hot iron when struck by the blacksmith's hammer are protoxide of iron.

The *peroxide of iron* is a very good absorbent of ammonia, and consequently, as will be hereafter described, adds to the fertility of the soil.

OXIDE OF MANGANESE, though often found in small quantities in the ashes of cultivated plants, cannot be considered indispensable.

Having now examined the materials from which the ashes of plants are formed, we are enabled to classify them in a simple manner, so that they may be recollected. They are as follows :—

ALKALIES.	ACIDS.	NEUTRALS.
Potash.	Sulphuric acid.	Chlorine.
Soda.	Phosphoric "	Oxide of Iron.
Lime.	Silicic "	" Manganese.
Magnesia.		

CHAPTER V.

GROWTH.

HAVING examined the materials of which plants are made, it becomes necessary to discover how they are put together in the process of growth. Let us therefore suppose a young wheat-plant, for instance, to be in condition to commence independent growth.

It consists of roots which are located in the soil; leaves which are spread in the air, and a stem which connects the roots and leaves. This stem contains sap vessels, which may be regarded, for the sake of simplicity, as tubes extending from the ends of the roots to the surfaces of the leaves, thus affording a passage for the sap, and consequently allowing the matters taken up to be distributed throughout the plant.

It is necessary that the materials of which plants are made should be supplied in certain proportions, at the proper time, and in a suitable condition. For instance, carbon could not be taken up in large quantities by the leaves, unless the roots, at the same time, were receiving from the soil those mineral matters which are necessary to growth. On the other hand, no considerable amount of earthy matter could be appropriated by the roots unless the leaves were obtaining carbon from the air. This same rule holds true with regard to all of the constituents required; Nature seeming to have made it a law that if one of the important ingredients of the plant is absent, the others, though they may be present in sufficient quantities, cannot be used. Thus, if the soil is deficient in alkalies, and still has sufficient quantities of all of the other ingredients, the plant cannot take up these ingredients, because alkalies are necessary to its life.

If a farmer wishes to make a cart he prepares his wood and iron, gets them all in the proper condition, and then can very readily put them together. But if he has all of the *wood* necessary and no *iron*, he cannot make his cart, because bolts, nails and screws are required, and their place cannot be supplied by boards. This serves to illustrate the fact that in raising plants we must give them everything that they require, or they will not grow at all.

In the case of our young plant the following operations are going on at about the same time.

The leaves are absorbing carbonic acid from the atmosphere, and the roots are drinking in water from the soil.

The manner in which food is taken up by roots, may be illustrated by the following experiment: Take a tumbler, filled entirely full with water; tie over it a bladder, and on the bladder sprinkle a little salt. The bladder becomes moist throughout its entire thickness, and transmits enough moisture to the salt to dissolve it gradually, and as fast as it is dissolved, it passes through the bladder into the water inside of the tumbler. In a long enough time the water can be made, in this way, to dissolve as much salt as though it had been stirred into it without the intervention of the bladder. If we keep the salt soaking wet, as it lies on the outside of the bladder, it will pass through much more rapidly, but if we do not wet it by a direct application of water, enough water will reach it through the membrane to allow it to pass into the tumbler, as above described.

The roots of plants contain sap, which is separated from the plant-food in the soil, by a thin film of matter, which constitutes its cell-walls. So long as the water of the sap has the capacity to dissolve more mineral matter than it already contains, it will take it through the cell-walls, as the salt is taken through the bladder. If the plant-food outside of the roots is in a moist condition, it will be taken up more rapidly than if too dry. The moisture of the soil itself, containing mineral matter in solution, passes through the cell-walls to supply the place of that which has been evaporated at the leaves, the matters in solution passing through with the water itself.

In short, there is a constant tendency to supply the deficiency of water in the root, and to keep it constantly charged with as much as it can dissolve of the plant-food, from which it is separated only by its membranous cell-walls.

Under the influence of daylight, the carbonic acid is decomposed; its oxygen returned to the atmosphere, and its carbon retained in the plant.

The water taken in by the roots circulates through the sap vessels of the plant, and is drawn up towards the leaves, where it is evaporated. This water contains the *nitrogen* and earthy food required by the plant and some carbonic acid, while the water itself consists of *hydrogen* and *oxygen*.

Thus we see that the plant obtains its food in the following manner:—

CARBON.—In the form of *carbonic acid* from the atmosphere, and from that contained in the sap, the oxygen being returned to the air.

OXYGEN & HYDROGEN.—From the elements of the water constituting the sap.

NITROGEN.—From the soil (chiefly in form of ammonia). It is carried into the plant through the roots in solution in water.

EARTHY MATTER.—From the soil, and only *in solution* in water.

Many of the chemical changes which take place in the interior of the plant are well, and some but imperfectly understood, but they require too much knowledge of chemistry to be easily comprehended by the young learner, and it is not absolutely essential that they should be understood by the scholar who is merely learning the *elements* of the science.

It is sufficient to say that the food taken up by the plant undergoes such changes as are required for its growth; as in animals, where the food taken into the stomach is digested, and is afterward formed into bone, muscle, fat, hair, etc., so in the plant the nutritive portions of the sap are resolved into wood, bark, grain, or other necessary parts.

The *results* of these changes are of the greatest importance in agriculture, and no person ought to be called a thoroughly *practical farmer* who does not understand them.

CHAPTER VI.

STARCH, WOODY-FIBRE, GLUTEN, ETC.

WE have hitherto examined the raw material of plants. That is, we have looked at each one of the elements separately, and considered its use in vegetable growth.

We will now consider another division of plants. We know that they consist of various substances, such as wood, gum, starch, oil, etc., and on examination we shall discover that these substances are composed of the various *atmospheric* and *earthy* ingredients described in the preceding chapters. They are made up almost entirely of *atmospheric* matter, but their ashy parts, though very small, are (as we shall presently see) of great importance.

These compounds may be divided into two classes.

The first class are composed of *carbon*, *hydrogen*, and *oxygen*.

The second class contain the same substances and *nitrogen*.

The first class (those compounds not containing nitrogen) comprise the wood, starch, gum, sugar, and fatty matter, which constitute the greater part of all plants, also the acids which are found in sour fruits, etc. Various as are all of these things in their characters, they are entirely composed of the same ingredients (carbon, hydrogen, and oxygen), and usually combined in *about* the same proportion. There may be a slight difference in the composition of their *ashes*, but the organic part derived from the atmosphere is much the same in every case, so much so, that they can often be artificially changed from one to the other.

As an instance of this, it may be stated that at the Fair of the American Institute, in 1834, Prof. Mapes exhibited samples of excellent sugar made from the juice of the corn-stalk, from starch, from linen, and from woody fibre.

In the plant, during its growth, they are constantly changing. At one time they assume a form in which they cannot be dissolved by water, and remain fixed in their places.

At another, the chemical influences on which growth depends, change them to a soluble form, and they are carried, by the circulation of the sap, to other parts of the organism, where they may be again deposited in other insoluble forms. For example, the turnip devotes the first season of its growth to storing up in its root a large amount of starch and pectic acid; in the second season, these substances become soluble, are taken up by the circulation and again deposited in the form of woody fibre, starch, etc., in the stems, leaves, seed-vessels, etc., above the ground. If a turnip root be planted in the spring, in moist cotton, from which it can get no food, it will simply, by the transformation of its own substance, form stems, leaves, flowers and seed.

Those products of vegetation which contain nitrogen, are of the greatest importance to the farmer, being the ones from which animal muscle is made.

They consist, as will be recollected, of carbon, hydrogen, oxygen and *nitrogen*, or of *all* of the *atmospheric* elements of plants. They are all of much the same character, though each kind of plant has its peculiar form of this substance, which is known under the general name of *protein*.

The protein of wheat is called *gluten*—that of In dian corn is *zein*—that of beans and peas is *legumin*. In other plants the protein substances are *vegetable albumen*, *casein*, etc.

Gluten absorbs large quantities of water, which causes it to swell to a great size, and become full of holes. Flour which contains much gluten, makes light, porous bread, and is preferred by bakers, because it absorbs so large an amount of water.

The nitrogenous substances are necessary to animal and vegetable life, and none of our cultivated plants will attain maturity, (complete their growth,) unless allowed the materials required for forming them. To furnish this condition is the chief object of nitrogen given to plants as manure. If no *nitrogen* could be obtained these substances could not be formed, and the plant must cease to grow.

When, on the contrary, *ammonia* is given to the soil, (by rains or otherwise,) it furnishes nitrogen, while the carbonic acid and water yield the other constituents of protein, and a healthy growth continues, *provided* that the soil contains the earthy matters required in the formation of the ash, in a condition to be taken up by the roots.

The wisdom of this provision is evident when we recollect that the nitrogenous substances are necessary to the formation of muscle in animals, for if plants were allowed to complete their growth without a supply of nitrogen, our grain and hay might not be sufficiently well supplied with it to keep our oxen and horses in working condition, while under the existing law, plants must be of nearly a uniform quality, (in this respect,) and if a field is short of nitrogen, its crop will not be large, and of a very poor quality, but the soil will produce good plants as long as the nitrogen lasts, and then the growth must cease.*

ANIMALS.

That this principle may be clearly understood, it may be well to explain more fully the application of the different constituents of plants in feeding animals.

Animals are composed (like plants) of atmospheric and earthy matter, and every thing necessary to build them up exists in plants. It is one of the offices of the vegetable world to prepare the gases in the atmosphere and the minerals in the earth for the uses of animal life, and, to effect this, plants put these gases and minerals together in the form of the various compound substances which we have just described.

In animals the compounds containing *no nitrogen* comprise the fatty substances, parts of the blood, etc., while the protein compounds, or those which

* It is of course assumed that the soil is fertile in other respects.

do contain nitrogen, form the muscle, a part of the bones, the hair, and other portions of the body.

Animals contain a larger proportion of earthy matter than plants do. Bones contain a large quantity of phosphate of lime, and we find other earthy compounds performing important offices in the system.

In order that animals may be perfectly developed, they must, of course, receive as food all of the materials required to form their bodies. They cannot live if fed entirely on one ingredient. Thus, if *starch* alone be eaten by the animal, he might become *fat*, but his strength would soon fail, because his food contains nothing to keep up the vigor of his *muscles.* If on the contrary the food of an animal consisted entirely of *gluten*, he might be very strong from a superior development of muscle, but would not become fat. Hence we see, that in order to keep up the proper proportion of both fat and muscle in our animals, (or in ourselves,) the food must be such as contains a proper proportion of both classes of vegetable products.

It is for this reason that grain, wheat for instance, is so good for food. It contains both classes of proximates, and furnishes material for the formation of both fat and muscle. The value of *flour* depends very much on the manner in which it is manufactured. This will be explained hereafter.

Apart from the relations between the *organic parts* of plants, and those of animals, there exists an important relation between their *ashes* or their *earthy* parts; and food, in order to satisfy the demands of animal life, must contain the mineral matter required for the purposes of that life. Take bones for instance. If phosphate of lime is not always supplied in sufficient quantities in the food, animals are prevented from forming healthy bones. This is particularly to be noticed in teeth. Where food is deficient of phosphate of lime, we see poor teeth as a result. Some physicians have supposed that one of the causes of consumption is the deficiency of phosphate of lime in food.

The first class of vegetable constituents (starch, sugar, gum, etc.) perform an important office in the animal economy aside from their use in making fat. They constitute the *fuel* which supplies the animal's fire, and gives him his *heat.* The lungs are the delicate stoves, which supply the whole body with heat. But let us explain this matter more fully. If wood, starch, gum, or sugar, be burned in a stove, they produce heat. These substances consist, as will be recollected, of carbon, hydrogen, and oxygen, and when they are destroyed in any way, (provided they be exposed to the atmosphere,) the hydrogen and oxygen unite and form water, and the carbon unites with the oxygen of the air and forms carbonic acid, as was explained in a preceding chapter. This process is always accompanied by the production of *heat*, and the *intensity* of this heat depends on the *time* occupied in its production. In slow decay, the chemical changes take place so slowly that the heat, being conducted away as soon as formed, is not per ceptible to our senses. In combustion (or burning) the same changes take place with much greater rapidity, and the same *amount* of heat, being concentrated, or brought out in a far shorter time, it becomes intense, and therefore apparent. In the lungs and blood-vessels of animals the same law holds true. The blood contains matters belonging to this carbonaceous class, and they undergo, during its circulation, the changes which have been described under the head of combustion and decay. Their hydrogen and oxygen unite, and form the moisture of the breath, while their carbon is combined with the oxygen of the air drawn into the lungs, and is thrown out as carbonic acid. The same consequence—heat—results in this, as in the other cases, and this heat is produced with sufficient rapidity for the necessities of the animal. When he exercises violently, his blood circulates with increased rapidity, thus carrying carbon more rapidly to the lungs. The breath also becomes quicker, thus supplying increased quantities of oxygen. In this way the decomposition becomes more rapid, and the animal is heated in proportion.

Thus we see that food has another function besides that of forming animal matter, namely to supply heat. When the food does not contain a sufficient quantity of starch, sugar, etc., to answer the demands of the system, the *animal's own fat* is carried to the lungs, and there used in the production of heat. This important fact will be referred to again.

CHAPTER VII.

LOCATION OF THE DIFFERENT PARTS, AND VARIATIONS IN THE ASHES OF PLANTS.

Let us now examine plants with a view to learning the *location* of the various parts.

The stem or trunk of the plant or tree consists very largely of *woody fibre;* this also forms a large portion of the other parts except the seeds, and, in some instances, the roots. The roots of the potato contain large quantities of *starch*. Other roots, such as the *carrot* and *turnip*, contain *pectic acid*,* a nutritious substance resembling starch.

It is in the *seed*, however, that the more nutritive portions of most plants exist, and here they maintain certain relative positions which it is well to understand, and which can be best explained by reference to the following figures, as described by Prof. Johnston:—

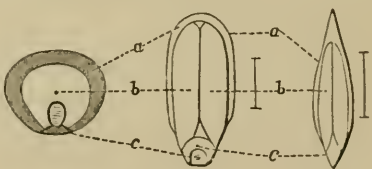

FIG. 1.

"Thus *a* shows the position of the oil in the outer

* This pectic acid gelatinizes food in the stomach, and thus renders it more digestible.

part of the seed—it exists in minute drops, inclosed in six-sided cells, which consist chiefly of gluten; *b*, the position and comparative quantity of the starch, which in the heart of the seed is mixed with only a small proportion of gluten; *c*, the germ or chit, which contains much gluten."*

The location of the *earthy* parts of plants is of much interest, and shows the adaptation of each part to its particular use. Take a wheat plant, for instance—the stalk, the leaf, and the grain, show in their ashes, important difference of composition. The stalk or straw contains three or four times as large a proportion of ash as the grain, and a no less remarkable difference of composition may be noticed in the ashes of the two parts. In that of the straw, we find a large proportion of silicic acid and scarcely any phosphoric acid, while in that of the grain there is scarcely a trace of silicic acid, although phosphoric acid constitutes about one half of the entire weight. The leaves contain a considerable quantity of lime.

This may at first seem an unimportant matter, but on examination we shall see the use of it. The straw is intended to support the grain and leaves, and to convey the sap from the roots to the upper portions of the plant. To perform these offices, *strength* is required, and this is given by the *silicic acid*, and the woody fibre which forms so large a proportion of the stalk. The silicic acid is combined with an alkali, and constitutes the glassy coating of the straw. While the plant is young, this coating is

* See Johnston's Elements, page 41.

hardly apparent, but as it grows older, as the grain becomes heavier, (verging towards ripeness,) the silicious coating of the stalk assumes a more prominent character, and gives to the straw sufficient strength to support the golden head. The straw is not the most important part of the plant as *food*, and it contains but little phosphoric acid, which is so necessary to animals.

The grain, on the contrary, is especially intended as food, and therefore must contain a large proportion of phosphoric acid—this being, as we have already learned, necessary to the formation of bone—while, as it has little necessity for strength, and as silicic acid is not needed by animals, this ingredient exists in the grain only in a very small proportion. It may be well to observe that the phosphoric acid of grain exists most largely in the hard portions near the shell, or bran. This is one of the reasons why Graham (or unbolted) flour is more wholesome than fine flour. It contains all of the nutritive materials which render the grain valuable as food, while flour which is very finely bolted* contains only a small part of the outer portions of the grain (where the phosphoric acid, protein and fatty matters exist most largely). The starchy matter in the interior of the grain, which is the least capable of giving strength to the animal, is carefully separated, and used as food for man, while the better portions, not being ground so finely, are rejected. This one thing alone may be sufficient to account for the fact, that the lives of

* Sifted through a fine cloth called a bolting cloth.

men have become shorter and less blessed with health and strength, than they were in the good old days when a stone mortar and a coarse sieve made a respectable flour mill.

Another important fact concerning the ashes of plants is the difference of their composition in different plants. Thus, the most prominent ingredient in the ash of the potato is *potash;* of wheat and other grains, *phosphoric acid;* of meadow hay, *silicic acid;* of clover, *lime;* of beans, *potash*, etc. In grain, *potash* (or *soda*), etc., are among the important ingredients.

These differences are of great importance to the practical farmer, as by understanding what kind of plants uses the most of one ingredient, and what kind requires another in large proportion, he can regulate his crops so as to prevent his soil from being exhausted more in one ingredient than in the others, and can also manure his land with reference to the crop which he intends to grow. The tables of analyses in the fifth section will point out these differences approximately. The composition of ashes varies a little, but not enough to affect the value of the tables for the uses of the farmer.

CHAPTER VIII.

RECAPITULATION.

We have now learned as much about the plant as is required for our immediate uses, and we will carefully reconsider the various points with a view to fixing them permanently in the mind.

Plants are composed of atmospheric and earthy matter.

Atmospheric matter is that which burns away in the fire. Earthy matter is the ash left after burning.

The organic matter of plants consists of three gases, oxygen, hydrogen and nitrogen, and one solid substance, carbon (or charcoal). The mineral parts consist of potash, soda, lime, magnesia, sulphuric acid, phosphoric acid, silicic acid, chlorine, oxide of iron, and oxide of manganese.

Plants obtain their atmospheric food as follows:—Oxygen and hydrogen from water; nitrogen from some compound containing nitrogen (chiefly from ammonia); and carbon from the atmosphere, where it exists as carbonic acid—a gas.

They obtain their earthy food from the soil.

The water which supplies oxygen and hydrogen to plants is readily obtained without the assistance of manures.

Ammonia is obtained from the atmosphere, by being absorbed by rain and carried into the soil, and it enters plants through their roots. It may be artificially supplied in the form of animal manure with advantage.

Carbonic acid is absorbed from the atmosphere by leaves, and decomposed in the green parts of plants under the influence of daylight; the carbon is retained, and the oxygen is returned to the atmosphere.

When plants are destroyed by decay, or burning, their organic constituents pass away as water, ammonia, carbonic acid, etc., ready again to be taken up by other plants.

The earthy matters in the soil can enter the plant only with the aid of water. *Potash*, *soda*, *lime*, and *magnesia*, are soluble in their pure forms. Magnesia is injurious when present in too large quantities.

Sulphuric acid is often used as a manure, and is usually most available in the form of sulphate of lime or plaster. It is also valuable in its pure form to prevent the escape of ammonia from composts.

Phosphoric acid is highly important, from its frequent deficiency in worn-out soils. It is most readily taken up by plants under certain conditions which will be described in the section on manures.

Silicic acid is common sand, and must be united to an alkali before it can be used by the plant, because it is insoluble except when so united.

Chlorine is a constituent of common salt (chloride of sodium), and from this source may be obtained in sufficient quantities for manurial purposes.

Oxide of iron is iron rust. There are two oxides of iron, the *peroxide* (red) and the *protoxide* (black). The former is advantageous in the soil, and the latter poisons plants.

Oxide of manganese is often absent from the ashes of our cultivated plants.

The food of plants, both organic and earthy, must be present at the time when it is required and in sufficient quantity. In the plant, this food undergoes such chemical changes as are necessary to growth.

The compound substances contained in plants are of two classes, those not containing *nitrogen*, and those which do contain it.

The first class constitute nearly the whole plant.

The second class, although small in quantity, are of the greatest importance to the farmer, as from them all animal muscle is made.

Animals, like plants, are composed of both atmospheric and earthy matter, and their bodies are obtained directly or indirectly from plants.

The first class of compounds in animals comprise the fat, and like tissues.

The second class form the muscle, hair, gelatine of the bones, etc.

In order that they may be perfectly developed, animals must eat nitrogenized and non-nitrogenized food, and in the proportions required by their natures.

They require phosphate of lime and other mineral food which exists in plants.

Aside from their use in the formation of *fat*, substances of the first class are employed in the lungs and blood-vessels as fuel to keep up animal heat, which is produced (as in fire and decay) by their decomposition.

When the food is insufficient for the purposes of heat, the animal's own fat is decomposed, and carried to the lungs as fuel.

The stems, roots, branches, etc., of most plants consist principally of *woody fibre.*

Their seeds, and sometimes their roots, contain considerable quantities of *starch.*

The *nitrogenized substances* and the *oils* of most plants exist most largely in the seeds, therefore seeds are the most nutritious food for animals, because they contain the largest proportion of digestible matter.

The location of the different compounds in the plant, as well as of its mineral parts, shows a remarkable reference to the purposes of growth, and to the wants of the animal world, as is noticed in the difference between the construction of the straw and that of the kernel of wheat.

The reason why the fine flour now made is not so healthfully nutritious as that which contained more of the coarse portions, is that it is robbed of a large proportion of protein and phosphate of lime, while it contains an undue amount of starch, which is available only to form fat, and to supply fuel to the lungs.

Different plants have ashes of different composition. Thus—one may take from the soil large quantities of potash, another of phosphoric acid, and another of lime. By understanding these differences, we shall be able so to regulate our rotations that the soil may not be called on to supply more of one ingredient than of another, and thus it may be kept in balance.

The facts contained in this chapter are the *alpha-*

bet of agriculture, and the learner should become perfectly familiar with them, before proceeding further.

To enter more fully and more scientifically upon the consideration of the various properties of these substances, and of their relations to each other, would, no doubt, be in better accordance with the demands of accurate knowledge; but the foregoing is believed to be a perfectly true, although a very simple statement of the first principles of the growth and composition of plants, and is sufficient for the first steps in agricultural study.

A clear comprehension of what is herein set forth should have the effect of stimulating a further search, in which more extended treatises will become necessary.

SECTION SECOND.

THE SOIL.

SECTION SECOND.

THE SOIL.

CHAPTER I.

FORMATION AND CHARACTER OF THE SOIL.

In the foregoing section, we have studied the character of plants and the laws which govern their growth. We learned that one necessary condition for growth is a fertile soil, and we must examine the nature of different soils, in order that we may understand the relations between them and plants.

The soil is not to be regarded as a mysterious mass of dirt, whereon crops are produced by a mysterious process. Well ascertained scientific knowledge has proved beyond question that all soils, whether in America or Asia, whether in Maine or California, have certain fixed properties, which render them fertile or barren, and their fertility or barrenness depends, first of all, on the presence or absence of those minerals which constitute the ashes of vegetable productions.

The soil is a great chemical compound, and its chemical character is ascertained (as in the case of plants) by analyzing it, or taking it apart.

We first learn that fertile soils contain both atmospheric and earthy matter; but, unlike the plant, they usually possess much more of the latter than of the former.

In the plant, the atmospheric matter constitutes the most considerable portion of the whole. In the soil, on the contrary, it usually exists in very small quantities, while the earthy parts constitute nearly the whole bulk.

The atmospheric or organic part of soils consists of the same materials that constitute the atmospheric part of the plants, and is in reality decayed vegetable and animal matter. It is not necessary that this organic part of the soil should form any particular proportion of the whole, and indeed we find it varying from one and a half to fifty, and sometimes, in peaty soils, to over seventy per cent. All fertile soils contain some organic matter, although it seems to make but little difference in fertility, whether it be five or fifty per cent.

The earthy part of soils is derived from the crumbling of rocks. Some rocks (such as the slates in Central New York) decompose, and crumble rapidly on being exposed to the weather; while granite, marble, and other rocks, will last for a long time without perceptible change. The *causes* of this crumbling are various, and are important to be understood by the agriculturist, as by the same processes by which the soil was originally formed, he can increase its depth, or otherwise improve it. This being the case, we will in a few words explain some of the principal pulverizing agents.

1. The action of frost. When water lodges in the crevices of rocks, and *freezes*, it expands, and bursts the rock, on the same principle that causes it to break a pitcher in winter. This power is very great, and by its assistance large cannon may be burst. Of course, the action of frost is the same on a small scale as when applied to large masses of matter, and, therefore, we find that when water freezes in the *pores* * of rocks or stones, it separates their particles and causes them to crumble. The same rule holds true with regard to stiff clay soils. If they are *ridged* in autumn, and left with a rough surface exposed to the frosts of winter, they will become much lighter and finer; and can afterwards be worked with less difficulty.

2. The action of water. Many kinds of rock become so soft on being soaked with water, that they readily crumble.

3. The chemical changes of the constituents of the rock. Many kinds of rock are affected by exposure to the atmosphere, in such a manner, that changes take place in their chemical character, and cause them to fall to pieces. The red kellis of New Jersey, (a species of sandstone,) is, when first quarried, a very hard stone, but on exposure to the influ-

* The spaces between the particles.

ences of the atmosphere, it becomes so soft that it may be easily crushed between the thumb and finger.

Other actions, of a less simple kind, exert an influence on the stubbornness of rocks, and cause them to be resolved into soils.* Of course, the composition of the soil must be similar to that of the rock from which it was formed; and consequently, if we know the chemical character of the rock, we can tell whether the soil formed from it can be brought under profitable cultivation. Thus felspar, on being pulverized, yields potash; talcose slate yields magnesia; marls yield lime, etc.

The soil formed entirely from rock, contains, of course, no organic matter. Still, it is capable of bearing plants of a certain class, and when these die, they are deposited in the soil, and thus form its organic portions, rendering it capable of supporting those plants which furnish food for animals. Thousands of years must have been occupied in preparing the earth for habitation by man.

As the earthy part of the soil is usually the largest, we will consider it first.

As we have stated that this portion is formed from rocks, we will examine their character, with a view to showing the different qualities of soils.

As a general rule, it may be stated that *all rocks*

* In very many instances the crevices and seams of rocks are permeated by roots, which, by decaying and thus inducing the growth of other roots, cause these crevices to become filled with organic matter. This, by the absorption of moisture, may expand with sufficient power to burst the rock.

are either sandstones, limestones, or clays; or a mixture of two or more of these ingredients. Hence we find that all mineral soils are either *sandy*, *calcareous* (limey), or *clayey;* or consist of a mixture of these, in which one or another usually predominates. Thus, we speak of a sandy soil, a clay soil, etc. These distinctions (sandy, clayey, loamy, etc.) are important in considering the *mechanical* character of the soil, but have little reference to its chemical conditions of fertility.

By *mechanical* character, we mean those qualities which affect the ease of cultivation—excess or deficiency of water, ability to withstand drought, etc. For instance, a heavy clay soil is difficult to plow, retains water after rains, and bakes quite hard during drought; while a light sandy soil is plowed with ease, often allows water to pass through immediately after rains, and becomes dry and powdery during drought. Notwithstanding those differences in their mechanical character, both soils may be very fertile, or one more so than the other, without reference to the clay and sand which they contain, and which, to *our observation*, form their leading characteristics. The same facts exist with regard to a loam, a calcareous (or limey) soil, or a vegetable mould. Their mechanical texture is not necessarily an index to their fertility, nor to the manures required to enable them to furnish food to plants. It is true, that each kind of soil appears to have some general quality of fertility or barrenness which is well known to practical men, yet this is not founded on the fact that the clay or the sand, or the vegetable matter, enter more largely into the constitution of plants than they do when they are not present in so great quantities, but on certain other facts which will be hereafter explained.

As the following names are used to denote the character of soils, in ordinary agricultural description, we will briefly explain their application:

A *Sandy soil* is, of course, one in which sand largely predominates.

Clay soil, one where *clay* forms a large proportion of the soil.

Loamy soil, where sand and clay are more equally mixed.

Marl contains from five to twenty per cent. of carbonate of lime.

Calcareous soil more than twenty per cent.

Peaty soils, of course, contain large quantities of organic matter.*

We will now take under consideration that part of the soil on which depends its ability to supply food to the plant. This portion rarely constitutes more than five or ten per cent. of the entire soil, often much less—and it has no reference to the sand, clay, and vegetable matters which they contain. From analyses of many fertile soils, and of others which are barren or of poorer quality, it has been ascertained that the presence of certain ingredients is necessary to fertility. This may be bet-

* These distinctions are not essential to be learned, but are often convenient.

ter explained by the assistance of the following table:

In one hundred pounds.	Soil fertile without manure.	Good wheat soil.	Barren.
Organic matter	9.7	7.0	4.0
Silicic acid (sand)	64.8	74.3	77.8
Alumina (clay)	5.7	5.5	9.1
Lime	5.9	1.4	.4
Magnesia	.9	.7	.1
Oxide of iron	6.1	4.7	8.1
Oxide of manganese	.1		.1
Potash	.2	1.7	
Soda	.4	.7	
Chlorine	.2	.1	
Sulphuric acid	.2	.1	
Phosphoric acid	.4	.1½	
Carbonic acid	4.0		
Loss during the analysis	1.4	3.6½	.4
	100.0	100.0	100.0

The soil represented in the first and second columns might still be fertile with less organic matter, or with a larger proportion of clay (alumina), and less sand (silicic acid). These affect its *mechanical* character; but, if we look down the columns, we notice that there are small quantities of lime, magnesia and the other constituents of the ashes of plants (except oxide of manganese). It is not necessary that they should be present in the soil in the exact quantity named above, but *not one must be entirely absent, or greatly reduced in proportion.* By referring to the third column, we see that these ingredients are not all present, and the soil is barren. Even if it were supplied with all but one or two, potash and soda for instance, it could not support a crop without the assistance of manures containing these alkalies. The reason for this must be readily seen, as we have learned that no plant can arrive at maturity without the necessary supply of materials required in the formation of the ash, and these materials can be obtained only from the soil; consequently, when they do not exist there, it must be barren.

The earthy part of soils has two distinct offices to perform. The clay and sand form a mass of material into which roots can penetrate, and which support plants in their position. These parts also absorb heat, air and moisture, to serve the purposes of growth, as we shall see in a future chapter. The minute portions of soil, which comprise the acids, alkalies and neutrals, furnish plants with their ashes, and are the most necessary to the fertility of the soil.

GEOLOGY.

The relation between the earthy parts of soils and the rocks from which it was formed, is the foundation of Agricultural Geology. Geology may be briefly named the *science of the rocks.* It would not be appropriate in an elementary work, to introduce much of this study, and we will therefore simply state that the same kind of rock is of the same composition all the world over; consequently, if we find a soil in New England formed from any particular rock, and a soil from the same rock in Asia, their natural fertility will be the same in both localities. All rocks consist of a mixture of different kinds of minerals; and some, consisting chiefly of one ingredient, are of different degrees of *hardness*. Both of these qualities must affect the character of the soil, but it may be laid down as a rule that, *when the rocks of two locations are exactly alike, the soils formed from them will be of the same natural fertility, and in proportion as the chemical character of rocks changes, in the same proportion will the soils differ in fertility.*

In most districts the soil is formed from the rock on which it lies; but this is not always the case. Soils are often formed by deposits of matter brought by water from other localities. Thus the alluvial banks of rivers consist of matters brought from the country through which the rivers have passed. The river Nile, in Egypt, yearly overflows its banks, and deposits large quantities of mud brought from the uninhabited upper countries. The prairies of the West owe their soil chiefly to deposits by water. Swamps often receive the washings of adjacent hills; and, in these cases, their soil is derived from a foreign source.

We might continue to enumerate instances of the relations between soils and the sources whence they originated, thus demonstrating more fully the importance of geology to the farmer; but it would be beyond the scope of this work, and should be investigated by scholars more advanced than those who are studying merely the *elements* of agricultural science.

The mind, in its early application to any branch of study, should not be charged with intricate subjects It should master well the *rudiments*, before investigating those matters which should *follow* such understanding.

By pursuing the proper course, it is easy to learn all that is necessary to form a good foundation for a thorough acquaintance with the subject. If this foundation is laid thoroughly, the learner will regard plants and soils as old acquaintances, with whose formation and properties he is as familiar as with the construction of a building or a simple machine. A simple spear of grass will become an object of interest, forming itself into a perfect plant, with full development of roots, stems, leaves, and seeds, by processes with which he feels acquainted. The soil will cease to be mere dirt; it will be viewed as a compound substance, whose composition is a matter of interest, and whose care may become a source of intellectual pleasure. The commencement of study in any science must necessarily be wearisome to the untrained mind, but its more advanced stages amply repay the trouble of early exertions.

CHAPTER II.

USES OF ATMOSPHERIC MATTER.

It will be recollected that, in addition to its mineral portions, the soil contains atmospheric or organic matter in varied quantities. It may be fertile with but one and a half per cent. of atmospheric matter, and some peaty soils contain more than fifty per cent. or more than one-half of the whole.

The precise amount necessary cannot be fixed at any particular proportion; probably five parts in a hundred is better than a smaller amount.

The soil obtains its atmospheric matter in two ways. First, by the decay of roots and dead plants, also of leaves, which have been brought to it by wind, etc. Second, by the application of animal or vegetable manures.

When a crop of clover is raised, it obtains its carbon from the atmosphere; and, if it be plowed under, and allowed to decay, a portion of this carbon is deposited in the soil. Carbon constitutes nearly the whole of the dry weight of the clover, aside from the constituents of water; and when we calculate the immense quantity of hay and roots grown on an acre of soil in a single season, we shall find that the amount of carbon thus deposited is immense. If the clover be removed, and the roots only left to decay, the amount of carbon deposited would still be very great. The same is true in all cases where the crop is removed, and the roots remain to add to the organic or vegetable part of the soil. While undergoing decomposition, a portion of this matter escapes in the form of gas, and the remainder chiefly assumes the form of carbon (or charcoal), in which form it will always remain, without loss, unless driven out by fire. If a bushel of charcoal be mixed with the soil now, it will be the same bushel of charcoal, neither more nor less, a thousand years hence, unless some influence is brought to bear on it aside from the growth of plants. It is true that, in the case of the decomposition of organic matter in the soil, certain compounds are formed, known under the general names of *humus* and *humic acid*, which may, in a slight degree, affect the growth of plants, but their practical importance is of too doubtful a character to justify us in considering them. The application of manures, containing organic matter, such as peat, muck, animal manure, etc., supplies the soil with carbon on the same principle, and the decomposing matters also generate* carbonic acid gas while being decomposed. The agricultural value of carbon in the soil depends (as we have stated), not on the fact that it enters into the composition of plants, but on certain other important offices which it performs, as follows:—

1. It makes the soil more retentive of manures.

2. It causes it to appropriate larger quantities of the fertilizing gases of the atmosphere.

3. It gives it greater power to absorb moisture.

4. It renders it warmer.

1. Carbon (or charcoal) makes the soil retentive of manures, because it has in itself a strong power to absorb, and retain fertilizing matters. There is a simple experiment by which this power can be shown.

Ex.—Take two barrels of pure beach sand, and mix with the sand in one barrel a few handfuls of charcoal dust, leaving that in the other pure. Pour a pailful of the brown liquor of the barn-yard through the pure sand, and it will pass out at the

* Produce.

bottom unaltered. Pour the same liquor through the barrel containing the charcoal, and only pure water will pass through. The reason for this is that the charcoal retains all of the impurities of the liquor, and allows only the water to pass through. Charcoal is often employed to purify water for drinking, or for manufacturing purposes.

A rich garden-soil contains large quantities of carbonaceous matter; and if we bury in such a soil a piece of tainted meat or a fishy duck, it will, in a short time, be deprived of its odor, which will be entirely absorbed by the charcoal and clay in the soil.

Carbon absorbs gases, as well as the impurities of water; and, if a little charcoal be sprinkled over manure, or any other substance, emitting offensive odors, the gases escaping will be taken up by the charcoal, and the odor will be very much modified.

It has also the power of absorbing earthy matters, which are contained in water. If a quantity of salt water be filtered through charcoal, the salt will be retained, and the water will pass through pure.

We are now able to see how carbon renders the soil retentive of manures.

1st. Manures, which resemble the brown liquor of barn-yards, have their fertilizing matters taken out, and retained by it.

2d. The gases arising from the decomposition (*rotting*) of manure are absorbed by it.

3d. The soluble earthy portions of manure, which might in some soils leach down with water, are arrested and retained at a point at which they can be taken up by the roots of plants.

2. Carbon in the soil causes it to appropriate larger quantities of the fertilizing gases of the atmosphere, on account of its power, as just named, to absorb gases.

The atmosphere contains gases, which have been produced by the breathing of animals, by the decomposition of various kinds of organic matter, which are exposed to atmospheric influences, and by the burning of wood, coal, etc. These gases are chiefly ammonia and carbonic acid, both of which are largely absorbed by water, and consequently are contained in rain, snow, and dew, which, as they enter the soil, give up these gases to the carbon, and they there remain until required by plants. Even the air itself, in circulating through the soil, gives up fertilizing gases to the carbon, which it may contain.

3. Carbon gives to the soil power to absorb moisture, because it is itself one of the best absorbents in nature; and it has been proved by accurate experiment that peaty soils absorb moisture with greater rapidity, and part with it more slowly than any others.

4. Carbon in the soil renders it warmer, because it darkens its color. Black surfaces absorb more heat than light ones, and a black coat, when worn in the sun, is warmer than one of a lighter color. By mixing carbon with the soil, we darken its color, and render it capable of absorbing a greater amount of heat from the sun's rays.

It will be recollected that, when vegetable matter decomposes in the soil, it produces certain gases (carbonic acid, etc.), which either escape into the atmosphere, or are retained in the soil for the use of plants. The production of these gases is always accompanied by *heat*, which, though scarcely perceptible to our senses, is perfectly so to the growing plant, and is of much practical importance. This will be examined more fully in speaking of manures.

Another important part of the organic matter in the soil is that which contains *nitrogen.* This forms but a very small portion of the soil, but it is of very great importance to vegetation. As nitrogen in food is of absolute necessity to the growth of animals, so nitrogen in the soil is indispensable to the growth of cultivated plants. It is obtained by the soil in the form of ammonia (or nitric acid) from the atmosphere, or by the application of animal or vegetable matter. In some cases, manures called *nitrates** are used; and, in this manner, nitrogen is given to the soil.

We have now learned that the atmospheric matter in the soil performs the following offices:—

Organic matter thoroughly decomposed is chiefly *carbon*, and has the various effects ascribed to this substance on p. 68.

Organic matter in process of decay produces car-

* Nitrates are compounds of nitric acid (which consists of nitrogen and oxygen), and alkaline substances. Thus nitrate of potash (saltpetre), is composed of nitric acid and potash; nitrate of soda (cubical nitre or cubic-petre), of nitric acid and soda.

bonic acid and ammonia in the soil; its decay also causes heat.

Organic matters containing *nitrogen*, such as animal substances, etc., furnish ammonia, and other nitrogenous substances to the roots of plants.

CHAPTER III.

USES OF EARTHY MATTER.

THE offices performed by the earthy constituents of the soil are many and important.

These, as well as the different conditions in which the bodies exist, are necessary to be carefully considered.

Those parts which constitute the larger proportion of the soil, namely the clay, sand, and limy portions, are useful for purposes which have been named in the first part of this section, while the *clay* has an additional effect in the absorption of ammonia.

For this purpose, it is quite as effectual as charcoal; the gases escaping from manures, as well as those existing in the atmosphere, and in rain-water, being arrested by clay as well as by charcoal.

The more minute ingredients of the soil—those which enter into the construction of plants—exist in conditions which are more or less favorable or injurious to vegetable growth. The principal condition necessary to fertility is *capacity to be dissolved*, it being (so far as we have been able to ascertain) a fixed rule, as was stated in the first section, that *no mineral substance can enter into the roots of a plant except it be dissolved in water.*

The *alkalies* potash, soda, lime, and magnesia, are in nearly all of their combinations in the soil sufficiently soluble for the purposes of growth.

The *acids* are, as will be recollected, sulphuric, silicic, and phosphoric. These exist in the soil in combination with the alkalies, as sulphates, silicates, and phosphates, which are more or less soluble under natural circumstances. Phosphoric acid in combination with lime as phosphate of lime is but slightly soluble; but, when it exists or has existed in the compound known as *super*phosphate of lime, it is much more soluble, and consequently enters into the composition of plants with much greater facility. This matter will be more fully explained in the section on manures. Silicic acid exists in the soil usually in the form of *sand*, in which it is, as is well known, perfectly insoluble; and, before it can be used by plants, which often require it in large quantities, it must be made soluble, by combination with an alkali.

For instance, if there is a deficiency of soluble silicic acid in the soil, the application of an alkali, such as potash, which will unite with the sand, and form the silicate of potash, will give it the ability to be dissolved and carried into the roots of plants.

Chlorine in the soil is probably always in an available condition.

Oxide of iron exists, as has been previously stated, usually in the form of the *per*oxide (or red oxide). Sometimes, however, it is found in the form of the *prot*oxide (or black oxide), which is soluble and is poisonous to plants, and renders the soil unfertile. By loosening the soil in such a manner as to admit the air, and by removing stagnant water by draining, this compound takes up more oxygen, which renders it a *per*oxide, and makes it insoluble except in the slight degree required for plants. The oxide of manganese is probably of little consequence.

The usefulness of all of these matters in the soil depends largely on their *exposure* to the action of roots and of the circulating water in the soil; if they are in the *interior* of particles, they cannot be made use of; while, if the particles are so pulverized that their constituents are exposed on their surfaces, they become available, because water can immediately attack to dissolve them and roots can absorb them.

This is one of the great offices of plowing, harrowing, cultivating, and hoeing; the *lumps* of soil being thereby more broken up and exposed to the action of atmospheric influences, which are often necessary to produce a fertile condition of soil.

SUBSOIL.

The subsoil is usually of a different character from the surface soil, but this difference is more often the result of cultivation and the effect of vegetation than of a different original formation. The surface soil, from having been long cultivated, has been more opened to the influences of the air than is the case with the subsoil, which has never been disturbed so as to allow the same action. Again the growth of plants has supplied the surface soil with roots, which by decaying have given it organic matter, thus darkening its color, rendering it warmer, and giving it greater ability to absorb heat and moisture, and to retain manures. All of these effects render the surface soil more fertile than it was before vegetable growth commenced, unless, by the removal of crops, its earthy plant-food has been too much reduced; and, where frequent cultivation and manures have been applied, a still greater benefit has resulted. In most instances the subsoil may, by the same means, be gradually improved in condition until it equals the surface soil in fertility. The means of producing this result, also further accounts of its advantages, will be given under the head of *Cultivation* (Sec. IV.).

IMPROVEMENT.

From what has now been said of the character of the soil, it must be evident that, as we know the *causes* of fertility and barrenness, we may by the proper means inprove the character of all soils which are not now in the highest state of fertility.

Chemical analysis of the soil cannot give us any reliable indication of its fertility or barrenness; so much depends on the state of solubility of the mineral plant-food, on the uniformity of its distribution through the soil, on the extent to which it is exposed on the surface of particles, and probably on other conditions concerning which we are in doubt, or of which we are entirely ignorant, that the mere weighing and measuring of the laboratory, has very little, if any, value to the practical farmer.

We can learn something of the capacities of the soil from the character of the plants which grow naturally upon it, and much more from its ability to produce larger crops of one kind than of another; something from the effect of different mineral manures upon plants growing on it.

The best use to which the farmer can apply the teachings of chemistry is in making such improvements as the foregoing indications show to be necessary, and, above all, in giving to the soil for each crop, or for each rotation of crops, the full equivalent of the minerals that they take away.

An examination, such as any farmer may make, will show us its deficiencies in *mechanical* character, and we may apply the proper treatment to increase fertility. In some instances the soil may contain everything that is required, but not in the proper condition. For instance, in some parts of Massachusetts, there are nearly *barren* soils which show by analysis precisely the same chemical composition as the soil of the Miami valley of Ohio, one of the most *fertile* in the world. The cause of this great difference in their agricultural capabilities, is that the Miami soil has its particles finely pulverized; while in the Massachusetts soil the ingredients are combined within particles (such as pebbles, etc.), where they are out of the reach of roots.

In other cases, we find two soils, which are equally well pulverized, which are of the same color and texture, and which appear to be of the same character, yet having very different power to support crops. Chemical analysis, could it accurately show, not only the kinds and quantities of plant food contained in these soils, but the condition in which it exists as to solubility, etc., would undoubtedly indicate a very great difference between them.

All of these differences may be overcome by the use of the proper means. Sometimes it could be done at an expense which would be justified by the result; and at others, it might require too large an outlay to be profitable. It becomes a question of economy, not of ability, and science is able to estimate the cost.

A soil cannot be cultivated understandingly until it has been rigidly subjected to such examinations as will tell us, as nearly as any examination can tell it, what is necessary to render it fertile. Even after fertility is perfectly restored it requires thought and care to maintain it. The different ingredients of the soil must be returned in the form of manures as largely as they are removed by the crop, or the supply will eventually become too small for the purposes of vegetation.

SECTION THIRD.

MANURES.

SECTION THIRD.

MANURES.

CHAPTER I.

CHARACTER AND VARIETIES OF MANURES.

The study of the science of *manures* is one of the most important branches of the practical education of a farmer. No baker would be called a good practical baker, who kept his flour exposed to the sun and rain. No shoemaker would be called a good practical shoemaker, who used morocco for the soles of his shoes, and heavy leather for the uppers. No carpenter would be called a good practical carpenter, who tried to build a house without nails, or other fastenings. So with the farmer. He cannot be called a good practical farmer if he keeps the materials, from which he is to make plants, in such a condition, that they will have their value destroyed, uses them in the wrong places, or tries to put them together without having everything present that is necessary. Before he can work to the best advantage, he must know what manures are composed of, how they are to be preserved, where they are needed, and what kinds are required. True, he may from observation and experience, *guess* at results, but he cannot *know* that he is right, and that he gets his results in the cheapest and most economical way, until he has learned the facts above named. In this section of our work, we shall endeavor to convey some of the information necessary to this branch of *practical farming.*

We shall adopt a classification of the subject somewhat different from that found in most works on manures, but the *facts* are the same. The action of manures is either *mechanical* or *chemical*, or a combination of both. For instance: some kinds of manure improve the mechanical character of the soil, such as those which loosen stiff clay soils, or others which render light sandy soils compact—these are called *mechanical* manures. Some again furnish food for plants—these are called *chemical* manures.

Many mechanical manures produce their effects by means of chemical action. Thus *potash* combines chemically with sand in the soil. In so doing, it roughens the surfaces of the particles of sand, and renders the soil less liable to be compacted by rains. In this manner, it acts as a *mechanical* manure. The compound of sand and potash,* as well as the potash alone, may enter into the composition of plants, and

* Silicate of potash.

hence it is a *chemical* manure. In other words, potash belongs to both classes described.

It is important that this distinction should be well understood by the learner, as the words "mechanical" and "chemical" in connection with manures will be made use of through the following pages.

There is another class of manures which we shall call *absorbents.* These comprise those substances which have the power of taking up fertilizing matters, and retaining them for the use of plants. For instance, *charcoal* is an absorbent. As was stated in the section on soils, this substance is a retainer of all fertilizing gases and of many minerals. Other matters made use of in agriculture have the same effect. These absorbents will be spoken of more fully in their proper places.

TABLE.

MECHANICAL MANURES are those which improve the mechanical conditions of soils.
CHEMICAL " are those which serve as food for plants.

MANURES.

ABSORBENTS are those substances which absorb and retain fertilizing matters.

Manure may be divided into three classes, viz.: *organic*, *mineral*, and *atmospheric.*

ORGANIC manures comprise all *animal* and *vegetable* matters which are used to fertilize the soil, such as dung, swamp-muck, etc.

MINERAL manures are those which are of a purely *mineral* character, such as lime, ashes, etc.

ATMOSPHERIC manures consist of those organic manures which exist in the form of gases in the atmosphere, and which are absorbed by rains and carried to the soil. These are of the greatest importance. The ammonia and carbonic acid in the air are atmospheric manures.

CHAPTER II.

ANIMAL EXCREMENT.

THE first organic manure which we shall examine, is animal *excrement*.

This is composed of those matters which have been eaten by the animal as food, and have been thrown off as solid or liquid manure. In order that we may know of what they consist, we must refer to the composition of food and examine the process of digestion.

The food of animals, we have seen to consist of both atmospheric and earthy matters. The atmospheric part may be divided into two classes, *i. e.*, that portion which contains nitrogen—such as gluten, albumen, etc., and that which does not contain nitrogen—such as starch, sugar, oil, etc.

The earthy part of food may also be divided into *soluble* matter and *insoluble* matter.*

DIGESTION AND ITS PRODUCTS.

Let us suppose that we have a full-grown ox, which is not increasing in any of his parts, but only consumes food to keep up his respiration, and to supply the natural wastes of his body. To this ox we will feed a ton of hay which contains organic matter, with and without nitrogen, and soluble and insoluble earthy substances. Now let us try to follow the food through its changes in the animal, and see what becomes of it. Liebig compares the consumption of food by animals to the imperfect burning of wood in a stove, where a portion of the fuel is resolved into gases and ashes (that is, it is completely burned), and another portion, which is not thoroughly burned, passes off as *soot*. In the animal action in question, the food undergoes changes which are similar to this burning of wood. A part of the food is *digested* and taken up by the blood, while another portion remains undigested, and passes the bowels as solid dung—corresponding to the soot of combustion. This part of the dung, then, we see is merely so much of the food as passes through the system

* No part of animal manure is permanently and entirely insoluble. It would perhaps be better to classify these substances as (1) those which are readily soluble, and (2) those which are but slowly soluble.

without being materially changed. Its nature is easily understood. It contains organic and mineral matters in nearly the condition in which they existed in the hay. They have been rendered finer and softer, but their *chemical* character (their composition) is not materially altered. The dung also contains small quantities of nitrogenous matter, which has *leaked out*, as it were, from the stomach and intestines. The digested food, however, undergoes further changes which affect its character, and it escapes from the body in three ways—*i. e.*, through the lungs and skin, through the bladder, and through the bowels. It will be recollected from the first section of this book, p. 20, that the carbon in the blood of animals unites with the oxygen of the air drawn into the lungs, and is thrown off in the breath as carbonic acid. The hydrogen and oxygen unite to form a part of the water which constitutes the moisture of the breath.

That portion of the atmospheric part of the hay which has been taken up by the blood of the ox, and which does not contain nitrogen, is emitted through the lungs. It consists, as will be recollected, of carbon, hydrogen, and oxygen, and these assume, in respiration, the form of carbonic acid and water.

The atmospheric matter of the digested hay, in the blood, which does contain nitrogen, goes to the *bladder*, where it assumes the form of urea—a constituent of urine or liquid manure.

We have now disposed of the imperfectly digested food (the dung), and of the *atmospheric* matter which was taken up by the blood. All that remains to be examined is the earthy matter in the blood, which would have become *ashes*, if the hay had been burned. The readily *soluble* part of this earthy matter passes into the bladder, and forms the *earthy parts of urine.* The more *insoluble* part passes the bowels, in connection with the dung.

If any of the food taken up by the blood is not returned as above stated, it goes to form fat, muscle, hair, bones, or some other part of the animal, and as he is not growing (not increasing in weight) an equivalent amount of the body of the animal goes to the manure to take the place of the part retained.*

We now have our subject in a form to be readily understood. We learn that when food is given to animals it is not *put out of existence*, but is merely *changed in form;* and that in the impurities of the breath, we have a large portion of those parts of the food which plants obtain from air and from water; while the solid and liquid excrements contain all that was taken by the plants from the soil and from manures. The Solid Dung contains the undigested parts of the food, the more *insoluble* parts of the ash, and the nitrogenous matters which have *escaped* from the digestive organs.

* This account of digestion is not, perhaps, strictly accurate in a physiological point of view, but it is sufficiently so to give an elementary understanding of the character of excrement as manure.

The LIQUID MANURE contains the nitrogenous parts of the digested food, and the *soluble* parts of the ash.

The BREATH contains those parts of the fully digested food which contain carbon, hydrogen, and oxygen, but *no nitrogen*, or at least a very inconsiderable quantity of it.

CHAPTER III.

WASTE OF MANURE.

THE loss of manure is a subject which demands most serious attention. Until within comparatively few years, little was known of the true character of manures, and consequently of the importance of protecting them against loss.

The chief causes of waste are *evaporation* and *leaching*.

EVAPORATION.

Evaporation is the changing of a solid or liquid body to a vapory form. Thus common smelling salts, a solid, if left exposed, passes into the atmosphere in the form of a gas or vapor. Water, a liquid, evaporates, and becomes a vapor in the atmosphere.

This is the case with very many substances in organic nature, both solid and liquid: they are liable to assume a gaseous form, and become mixed with the atmosphere. They are not destroyed, but are changed in form.

As an instance of this action, suppose an animal to die and to decay on the surface of the earth. After a time, the flesh will entirely disappear, but is not lost. It no longer exists as the flesh of an animal, but its carbon, hydrogen, oxygen, and nitrogen, still exist in the air. They have been liberated from the attractions which held them together, and have passed away; but (as we already know from what has been said in a former section) they are ready to be again taken up by plants, and pressed into the service of life.

The evaporation of liquids may take place without the aid of anything but heat; but, in the case of solids, it is often assisted by decay and combustion, which break up the bonds that hold the constituents of bodies together, and thus enable them to return to the atmosphere, from which they were originally derived.

It must be recollected that everything which has an *odor* (or can be smelled) is evaporating. The odor is caused by parts of the body floating in the air, and acting on the nerves of the nose. This is an invariable rule; and when we perceive an odor, we may be sure that parts of the material from which it emanates are escaping. If we perceive the odor of an apple, it is because parts of the volatile oils of the apple enter the nose. The same is true when we smell hartshorn, cologne, etc.

The intensity of these odors bears no relation to the amount of the substance passing into the air; for instance, a grain of musk will continue to give off a strong odor for many years, while gum camphor, with a much less intense odor, wastes away very rapidly. Ammonia escapes rapidly.

Manures made by animals have an offensive odor, simply because volatile parts of the decomposing manure escape into the air, and are therefore made perceptible. All organic parts in turn may become volatile, assuming a gaseous form as they decompose.

We do not see the gases rising, but there are many ways by which we can detect them. If we wave a feather over a manure heap, from which ammonia is escaping, the feather having been recently dipped in muriatic acid, white fumes will appear around the feather, being the muriate of ammonia formed by the union of the escaping gas with the acid. Not only ammonia, but also carbonic acid, and other gases which are useful to vegetation escape, and are given to the winds. Indeed it may be stated in few words that all of the organic part of *plants* (all that was obtained from the air, from water, and from ammonia), constituting more than nine-tenths of their dry weight, may be evaporated by the assistance of decay or combustion. The atmospheric parts of *manures* may be lost in the same manner; and, if the process of decomposition be continued long enough, nothing but a mass of earthy matter will remain, except a small quantity of carbon which has not been resolved into carbonic acid.

The proportion of solid manure lost by evaporation (made volatile by the assistance of decay) may be a very large part of the whole. Manure cannot be kept a single day in its natural state without losing something. It commences to give out an offensive odor immediately, and this odor is often accompanied, as was before stated, by the loss of some of its fertilizing parts.

Animal manure contains, as will be seen by reference to p. 86, all of the substances contained in plants, though not always in the correct relative proportions to each other. When decomposition commences, the carbon unites with the oxygen of the air, and passes off as carbonic acid; the hydrogen and oxygen combine to form water (which evaporates), and the *nitrogen is mostly resolved into ammonia, which escapes into the atmosphere*, unless absorbed by substances artificially applied for the purpose, or retained by the carbon, organic acids, or other products of decomposition with which it may become united.

If manure is thrown into heaps, it often ferments so rapidly as to produce sufficien theat to set fire to some parts of the manure, and cause its gases to be thrown off with greater rapidity. This may be observed in nearly all heaps of animal excrement. When they have lain for some time in mild weather, gray streaks of *ashes* are often to be seen in the centre of the pile. The organic part of the manure having been *burned* away, nothing but the ash remains,—this is called *fire-fanging.*

Manures kept in cellars without being mixed with refuse matter are subject to some loss by evaporation unless they are so situated as to absorb the urine, when they are less likely to become injuriously heated.

When kept in the yard, they are much more liable to loss from excessive evaporation. They are here often saturated with the water of rains, which, in its evaporation, carries away ammonia and carbonic acid which it has obtained from the rotting mass. The evaporation of the water is rapidly carried on, on account of the great extent of surface. The whole mass is spongy, and soaks the liquids up from below (through hollow straws, etc.), to be evaporated at the surface on the same principle as causes the wick of a lamp to draw up the oil to supply fuel for the flame.

Liquid Manure containing large quantities of nitrogen, and forming much ammonia, is also liable to lose all of its organic parts from evaporation (and fermentation), so that it is rendered as much less valuable as is the solid dung.

From these remarks, it may be justly inferred that a very large portion of the *value* of solid and liquid manure may be lost by evaporation in a sufficient length of time, depending on circumstances, whether it be a few months or several years. The wasting commences as soon as the manure is dropped, and continues, except in very cold weather, until the destruction is complete. Hence we see that true economy requires that the manures of the stable, sty, and poultry-house, should be protected (as will be hereafter described) as soon as possible after they are made.

LEACHING.

The subject of *leaching* is even more important in considering the earthy parts of manures than evaporation is to the atmospheric, while leaching also affects the atmospheric products of decay, they being absorbed by water to a great degree.

A good illustration of leaching is found in the manufacture of potash. When water is poured over wood-ashes, it dissolves their potash which it carries through in solution, making ley. If ley is boiled to dryness, it leaves the potash in a solid form, proving that this substance had been dissolved by the water and removed from the insoluble parts of the ashes.

In the same way, water in passing through manures takes up their soluble portions as fast as liberated by decomposition, and carries them to waste, and they are lost to the manure. There is but a small quantity of ash exposed for leaching in fresh dung; but, as the decomposition of the atmospheric part proceeds, it continues to develop it more and more (in the same manner as burning would do, only more slowly), thus preparing fresh supplies to be carried off with each shower. In this way, while manure may be largely injured by evaporation, the soluble parts may be removed by water until but a small remnant of its original fertilizing properties remains.

It is a singular fact concerning leaching, that water is able to carry no part of the organic constituents of vegetables to any considerable depth below the surface in a fertile soil. They would probably be carried to an unlimited distance in pure sand, as it contains nothing which is capable of arresting them; but, in most soils, the clay and carbon which they contain retain all of the ammonia; also nearly all of the matters which go to form the ashes of plants very near the surface of the soil. If such were not the case, the fertility of the earth must soon be destroyed, as all of those elements which the soil must supply to growing plants would be carried down out of the reach of roots, and leave the world a barren waste, its surface having lost its elements of fertility, while the downward filtration of these would render the water of wells and springs unfit for our use. Now, however, they are all retained near the surface of the soil, and the water issues from springs comparatively pure.

EVAPORATION removes from manure—

Carbon, in the form of carbonic acid.
Hydrogen and oxygen, in the form of water.
Nitrogen, in the form of ammonia.

LEACHING removes from manure—

The soluble and most valuable parts of the ash in solution in water, besides carrying away some of the above-named forms of organic matter.

CHAPTER IV.

ABSORBENTS.

Before considering further the subject of animal excrement, it is necessary to examine a class of manures known as *absorbents*. These comprise all matters which have the power of absorbing (or soaking up) the gases which arise from the evaporation of solid and liquid manures, and retaining them until required by plants.

The most important of these is undoubtedly clay, which forms a large part of nearly all fertile soils. The use of this in connection with manure will be spoken of in describing the treatment of *night-soil*. For ordinary use one of the most valuable absorbents is *charcoal*.

CHARCOAL.

Charcoal, in an agricultual sense, means all forms of carbon, whether as peat, muck, charcoal dust from the spark-catchers of locomotives, charcoal hearths, river and swamp deposits, leaf mould, decomposed spent tanbark or sawdust, etc. In short, if any vegetable matter is decomposed with the partial exclusion of air (so that there shall not be oxygen enough supplied to unite with all of the carbon), a portion of its carbon remains in the exact condition to perform the best agricultural offices of charcoal.

The operation of carbonaceous matter in the soil was explained in a former section (Sec. 2), and we will now examine merely its action with regard to manures. When properly applied to manures, in compost, it has the following effects:

1. It absorbs and retains the fertilizing gases evaporating from decomposing matters.

2. It acts as a *divisor*, thereby reducing the strength (or intensity) of powerful manures—thus rendering them less likely to injure the roots of plants; and also increases their bulk, so as to prevent *fire-fanging* in composts.

3. It in part prevents the leaching out of the soluble parts of the ash.

4. It keeps the compost moist.

The first-named office of charcoal, *i. e.*, absorbing and retaining gases, is one of the utmost importance. It is this quality that gives to it so high a position in the opinion of all who have used it. As was stated in the section on soils, carbonaceous matter seems to be capable of absorbing everything which may be of use to vegetation. It is a grand purifier, and while it prevents offensive odors from escaping, it is at the same time storing its pores with food for the nourishment of plants.

2d. In its capacity as a *divisor* for manures, charcoal is excellent in all cases, especially to use with strongly concentrated (or heating) animal manures. These, when applied in their natural state to the soil, are very apt to injure young roots by the violence of their action. When mixed with a divisor, such manures are *diluted*, made less active, and consequently less likely to be injurious. In composts, manures are liable, as has been before stated, to become burned by the resultant heat of decomposition; this process of combustion is prevented by the liberal use of divisors, because, by increasing the bulk, the heat, being diffused through a larger mass, becomes less intense. The same principle is exhibited in the fact that it takes more fire to boil a cauldron of water than a tea-kettlefull.

3d. Charcoal has much power to arrest the passage of mineral matters in solution; so much so, that compost heaps, well supplied with muck, are less affected by rains than those not so supplied. All composts, however, and all organic manures should be kept under cover until spread upon the land.

4th. Charcoal keeps the compost moist, from the ease with which it absorbs water, and its ability to retain it.

With these advantages before us, we must see the importance of an understanding of the modes for obtaining charcoal. Many farmers are so situated that they can obtain sufficient quantities of charcoal dust. Others have not the same facilities. Nearly all, however, can obtain *muck* or leaf mould, and to this we will now turn our attention.

MUCK AND ITS TREATMENT.

By *muck*, we mean the vegetable deposits of swamps and rivers. It consists of decayed organic substances, mixed with more or less earth. Its principal constituent is *carbon*, in different degrees of development, which has remained after the decomposition of vegetable matter. Muck varies largely in its quality according to the amount of carbon which it contains, and the completeness of its decomposition. The best muck is usually found in comparatively dry locations, where the water which once caused the deposit has been removed. Muck which has been long in this condition, is usually better decomposed than that which is saturated with water. The muck from swamps, however, may soon be brought to the best condition. It should be thrown out if possible at least a year before it is required for use, and left in small heaps or ridges, exposed to the action of the weather, which will assist in pulverizing it, while, from having its water removed, its decomposition goes on more rapidly.

After the muck has remained in this condition a sufficient length of time, it may be removed to the barn-yard and composted with a mixture of lime and salt (described on page 99 in the proportion of one cord of muck to four bushels of the mixture, or with slaked lime, or wood-ashes. At the end of a month or more, the muck in the compost will have been reduced to a fine pulverulent mass, the decomposition being hastened and made more complete by repeated turnings—nearly as valuable as charcoal dust for application to animal excrement. When in this condition it is called *prepared* muck, by which name it will be designated in the following pages.

Muck had better not be used immediately after being taken from the swamp, as it is then almost always *sour*. Its *sourness* is due to *acids* which it contains, and these must be rectified by the application of an alkali, or by long exposure to the weather, before the muck is suitable for use.

LIME AND SALT MIXTURE.

The mixture, lime and salt, used in the decomposition of muck, is made in the following manner:

RECIPE.—Take *three* bushels of shell lime, *hot from the kiln*, or as fresh as possible, and slake it with water in which *one* bushel of salt has been dissolved.

Care must be taken to use only so much water as is necessary to dissolve the salt, as it is difficult to induce the lime to absorb even so large a quantity.

In dissolving the salt, it is well to hang it in a basket in the upper part of the water, as the salt water will immediately settle towards the bottom (being heavier), and allow the freshest water to be nearest to the salt. In this way the salt may be all dissolved, and thus make the brine used to slake the lime. It will be necessary to apply the brine at intervals of a day or two, and to stir the mass often, as the amount of water is too great to be readily absorbed.

This mixture should be made under cover, as, if exposed, it would obtain moisture from rain or dew which would prevent the use of all the brine

Another objection to its exposure to the weather is its liability to be washed away by rains. It should be at least ten days old before being used. and would be improved by an age of three or four months, as the chemical changes it undergoes will require some time to be completed.

The character of this mixture is not very clearly understood. Its principal constituents are lime, carbonic acid, chlorine, and soda. The salt is undoubtedly decomposed in part or entirely, and various compounds, containing the above substances in different proportions and in different forms of combination, are formed. Probably the extent of the decomposition of the salt and the character of the new combinations depend on various circumstances, and vary considerably.

These compounds are much better agents in the composition of muck than pure salt and lime.

When *shell* lime cannot be obtained, Thomaston, or any other very pure lime, will answer; but care must be taken that it do not contain much magnesia.

LIME.

Muck may be decomposed by the aid of other materials. *Lime* is very efficient, though not so much so as when combined with salt. The action of lime, when applied to the muck, depends very much on its condition. Air-slaked lime (carbonate of lime) has less effect than hydrate of lime (lime simply slaked with water), because it is less caustic in its character.

POTASH.

Potash is a very active agent in decomposing vegetable matter, and may be used with great advantage, especially where the soil which is to be manured is deficient in potash.

Unleached wood-ashes are generally the best source from which to obtain this, and from five to twenty-five bushels of these mixed with one cord of muck will have a capital effect.*

The sparlings (or refuse) of potash warehouses may often be purchased at sufficiently low rates to be used for this purpose, and answer an excellent end. They may be applied at the rate of from twenty to one hundred pounds to each cord of muck.

By any of the foregoing methods, muck may be *prepared* for use in composting.

CHAPTER V.

COMPOSTING STABLE MANURE.

In composting stable manure in the most economical manner, the evaporation of the gases which result from its decomposition, and the leaching out of the ashy (and other) portions which decomposition has

* *Leached* ashes will not supply the place of these, as the leaching has deprived them of most of their potash.

set free must be avoided, while the mass is kept in such condition as to admit of the perfect decomposition of the manure.

Solid manures in their fresh state are of but very little use to plants. It is only as they are decomposed, and have their nitrogen turned into ammonia, and their other ingredients prepared to be taken up again by plants, that they are of much value as fertilizers, although there are of course certain advantages resulting from their fermentation in the ground, while there is no better way to avoid loss than by plowing fresh manure directly into the soil. We have seen that, if decomposition takes place without proper precautions being taken, the most valuable parts of the manure would be lost. Nor is it advisable, when an immediate effect is wanted, to keep manures from decomposing until they are applied to the soil, for then they are not immediately ready for use, and time is lost. By composting, we aim to save everything while we prepare the manures for immediate use.

SHELTER.

The first consideration in preparing for composting is to provide proper shelter. This may be done either by means of a shed or by arranging a cellar under the stables, or in any other manner that may be dictated by circumstances. It is no doubt better to have the manure shed enclosed so as to make it an effectual protection; this, however, is not absolutely necessary if the roof project far enough over the compost to shelter it from the sun's rays and from driving rains.

The importance of some protection of this kind is evident from what has already been said, and indeed it is impossible to make an economical use of manures without it. The trifling cost of building a shed, or preparing a cellar, is amply repaid in the benefit resulting from their uses. If an open shed is used, care should be taken to so arrange the slope of the ground that no surface water can reach the manure.

THE FLOOR.

The *floor* or foundation on which to build the compost deserves some consideration. It may be of plank tightly fitted, a hard bed of clay, or better, a cemented surface. Whatever material is used in its construction (and stiff clay mixed with water and beaten compactly down answers an excellent purpose), the floor must have such an inclination as will cause it to discharge water only at one point. That is, one part of the edge must be lower than the rest of the floor, which must be so shaped that water will run towards this point from every part of it; then—the floor being water-tight—all the liquids of the compost may be collected in a

TANK.

This *tank*, used to collect the liquids of the manure, may be made by sinking a barrel or hogshead (according to the size of the heap) in the ground at the point where it is required, or in any other convenient manner.

In the tank a pump of cheap construction may be placed, to raise the liquid to a sufficient height to be conveyed by a trough to the centre of the heap, and there distributed by means of a perforated board

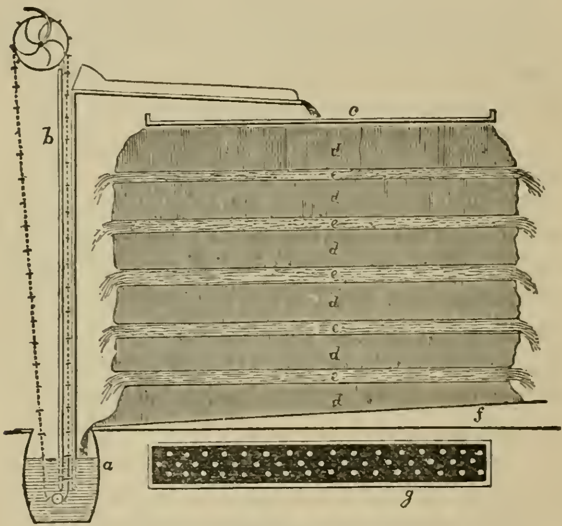

FIG. 2.

a, tank; *b*, pump; *c* and *g*, perforated board; *d*, muck; *e*, manure; *f*, floor.

with raised edges, and long enough to reach across the heap in any direction. By altering the position of this board, the liquid may be carried evenly over the whole mass.

The appearance of the apparatus required for composting, and the compost laid up, may be better shown by the foregoing figure.

The compost is made by laying on the floor ten or twelve inches of muck, and on that a few inches of manure, then another heavy layer of muck, and another of manure, continuing in this manner until the heap is raised to the required height, always having a thick layer of muck at the top.

After laying up the heap, the tank should be filled with liquid manure from the stables, slops from the house, soap-suds, or other water containing fertilizing matter, to be pumped over the mass. There should be enough of the liquid to saturate the heap and filter through to fill the tank once or twice a week, at which intervals it should be again pumped up, thus continually being passed through the manure. This liquid should not be changed, as it contains much soluble manure. Should the liquid manures named above not be sufficient, the quantity may be increased by the use of rain-water. That falling during the first ten minutes of a shower is the best, as it contains the most ammonia.

The effects produced by frequently watering the compost constitute one of the greatest advantages of this system.

The soluble portions of the manure are equally diffused through every part of the heap.

Should the heat of fermentation be too great, the watering will reduce it.

When the compost is saturated with water, the air is driven out; and, as the water subsides, *fresh* air enters and takes its place. The fresh air contains oxygen, which assists in the decomposition of the manure.

In short, the watering does all the work of forking over by hand much better and much more cheaply.

At the end of a month or more, this compost will be ready for use. The layers in the manure will have disappeared, the whole mass having become of a uniform character, highly fertilizing, and ready to be immediately used by plants.

It may be applied to the soil, either as a top-dressing, or otherwise, without fear of loss, as the muck will retain all of the gases which would otherwise evaporate.

The cost and trouble of the foregoing system of composting are trifling compared with its advantages. The quantity of the manure is much increased, and its quality improved. The health of the animals is secured by the retention of those gases, which, when allowed to escape, render impure the air that they have to breathe.

The cleanliness of the stable and yard is much improved, as the effete matters, which would otherwise litter them, are carefully removed to the compost.

The system of composting described above is the most complete that has yet been suggested for making use of solid manures. Many other methods may be adopted when circumstances will not admit of so much attention. It is a common and excellent practice to throw prepared muck into the cellar under the stables, to be mixed and turned over with the manure by swine. In other cases the manures are kept in the yard, and are covered with a thin layer of muck every morning. The principle which renders these systems beneficial is that of the absorbent power of charcoal.

The composting of stable manure, although always advantageous, frequently requires more labor, and more expensive accommodations than can be given to it. There is no doubt that, where proper facilities can be obtained for carrying out the foregoing directions, they will be found profitable. Those who are obliged to use their stable manure with the least possible amount of handling, or who cannot procure muck or other organic matter to add to it, should at least manage to keep it entirely sheltered from the rain until it is hauled out on to the land. Manure kept under a shed, necessarily loses some ammonia; but the amount of this loss has been found to be very small, for the reason that, during the decomposition of the straw and coarser vegetable parts, certain organic acids and other compounds are produced, which combine with or absorb most of the ammonia as it is generated.

The loss of ammonia, and of the soluble constituents of the ash, is greater when the decomposition takes place without protection from the rain.

The best plan is, undoubtedly, to have a cellar under the stable to receive the manure as soon as dropped, and to protect it, as far as possible, from all atmospheric influences.

For a long time one of the strongest recommendations of "book farming" was directed *against* the practice of spreading manure upon the land more than a day or two before it could be plowed under. But on this point, practice has gained a triumph over a crude theory. There is no doubt that manure so spread is subject to some waste; but that which is not wasted is so much better incorporated with the soil by the water of rains, which distributes its soluble parts evenly among all of its particles, that the effect produced is better than if the raw manure had been immediately plowed under, necessarily somewhat irregularly and in spots. In this latter case there would be no loss of material, but some parts of the soil would receive more than was necessary, while others would be deprived of any material benefit, and the land would be less fertile than if every root were sure to find, in every part of the soil, its due proportion of the food. Ammonia is formed only during decomposition; and, especially during cold weather, there is very little decomposition going on in manure which is thinly spread upon the surface of the land; hence the loss from this cause is not great.

In the case of very heavy manuring, especially with undecomposed manure on clay land, there is a great benefit arising from the fermentation of the dung in the soil,—a chemical action producing a mechanical effect,—but ordinarily it is at least a question whether it is not best to spread the manure on the surface as long as possible before plowing, unless in the case of land which is to be plowed in the fall for spring crops, when it is well to spread the manure after plowing, to be harrowed in in the spring.

This practice is of course not admissible on steep hill-sides or other surfaces where the manure would be subjected to the danger of being washed away by water flowing over the surface in winter or spring.

Different circumstances necessarily require a different treatment of manure; but the following principles are applicable to all cases:

1. All organic manures are much improved by being thoroughly decomposed before being applied to the land.

2. It is always advantageous (though not always advisable) that their fermentation take place in the compost heap, where they give a part of their value to muck or other refuse organic matter, which prevents all waste of fertilizing gases.

3. All animal manures should be carefully protected against sun, rain, and wind, from the time they are dropped until they are spread upon the land.

4. The solid dung should always be so kept that it will absorb the urine.

5. For the *mechanical* improvement of the soil, raw manure should be deeply mixed with it.

6. For immediate fertilizing effect, well-rotted manure should be applied to, and harrowed in near the surface.

LIQUID MANURE.

Liquid manure from animals may, also, be made useful by the assistance of prepared muck. Where a tank is used in composting, the liquids from the stable may all be employed to supply moisture to the heap; but where any system is adopted, not requiring liquids, the urine may be applied to muck heaps, and there allowed to ferment. Fermentation is necessary in urine as well as in solid dung, before it is very active as a manure, although its decomposition is much more rapid than that of the dung. Urine, as will be recollected, contains nitrogen and forms ammonia on fermentation.

The urine should never be allowed to stand in pools to become mixed with rain-water, nor to run to waste; but should always be immediately absorbed either by the dung or by muck, or other refuse matter provided for the purpose.

By referring to the analysis of liquid and solid manure in Section V., their relative value may be seen.

CHAPTER VI.

DIFFERENT KINDS OF ANIMAL EXCREMENT.

THE manures of different animals are, of course, of different value as fertilizers, varying according to the food, the age of the animals, etc.

Yet the difference is not so great as would be supposed. The quality of manure depends very much more upon the food from which it is made than upon the animal by which it is made. Linseed meal or cotton-seed meal, which contains much nitrogen, and is rich in phosphates, makes manure worth infinitely more than that from straw and turnips. Whether these articles of food have passed through an ox or a hog, makes very little difference; though, as explained below, it does make some difference.

STABLE MANURE.

By stable manure we mean, usually, that of the horse, and that of horned cattle. The case described in Chapter II. (of this Section) was one where the animal was not increasing in any of its parts, but returned in the form of manure, and otherwise, the equivalent of everything eaten. This case is one of the most simple kind, and is subject to many modifications.

The *growing* animal is increasing in size, and as he derives his increase from his food, he does not return in the form of manure so much as he eats. If his bones are growing, he is taking from his food phosphate of lime and nitrogenous matter; consequently, the manure will be poorer in these ingredients. The same may be said of the formation of the muscles, in relation to nitrogen.

The *fattening* animal, if full grown, makes manure which is as good as that from animals that are not increasing in size, because the fat is taken from those parts of the food which are obtained by plants from the atmosphere, and from water (*i. e.* from the substances containing no nitrogen). Fat contains no nitrogen, and, consequently, does not lessen the amount of this ingredient in the manure.

Milch Cows use a part of their food for the formation of milk, and consequently they produce manure of reduced value.

The solid manure of the horse is better than that of the ox, while the liquid manure of the ox is comparatively better than that of the horse. The cause of this is, that the horse has less perfect digestive organs than the ox, and consequently passes more of the valuable parts of his food, in an undigested form, as dung; while the ox, from chewing the cud and having more perfect digestion, turns more of his food into urine than does the horse.

RECAPITULATION.

Full Grown animals not producing milk, and full grown animals fattening } make the best manure.

The Growing of Animals reduces the value of their manure, portions of their food being taken to form their bodies.

Milch Cows reduce the value of their manure by changing a part of their food into milk.

The Ox makes poor dung and rich urine.*
The Horse makes rich dung and poor urine.*

NIGHT SOIL.

The *best* manure within the reach of the farmer is *night soil*, or human excrement. The manure of man consists (as does that of any other animal) of those parts of his food which are not retained in the increase of his body. If he be *growing*, his manure is poorer, as in the case of the ox; and it is subject to all the other modifications named in the early part of this chapter. His food is usually of a varied character, and is rich in nitrogen, the phosphates, and other inorganic constituents; consequently, his manure is made valuable by containing large quantities of these matters. As is the case with the ox, the *dung* contains the undigested food, the secretions (or leakings) of the digestive organs, and the insoluble parts of the ash of the digested food. The *urine*, in like manner, contains a large proportion of the nitrogen and the soluble inorganic parts of the digested food. When we consider how much richer the *food* of man is than that of horned cattle, we shall understand the superior value of his *excrement*.

Night soil has been used as a manure, for ages, in China and Japan; and herein lies, undoubtedly, the great secret of their success in supporting a dense population, for almost countless ages, without impoverishing the soil.

* Comparatively.

Some have supposed that manuring with night soil would give disagreeable properties to plants: this is not the case; their quality is invariably improved. The color and odor ot the rose are made richer and more delicate by the use of the most offensive night soil as manure.

It is evident that this is the case from the fact that plants have it for their direct object to make over and put together the refuse organic matter and the gases and the minerals found in nature, for the use of animals. If there were no natural means of rendering the excrement of animals available to plants, the earth must soon be shorn of its fertility, as the elements of growth when once consumed would be essentially destroyed, and no soil could survive the exhaustion. There is no reason why the manure of man should be rejected by vegetation more than that of any other animal; and indeed it is not,—ample experience has proved that there is no better manure in existence.

A single experiment will suffice to show that night soil may be so kept that there shall be no loss of its valuable gases, and consequently no offensive odor arising from it, while it may be removed and applied to crops without unpleasantness. All that is necessary to effect this wonderful change in night soil, and to turn it from its disagreeable character to one entirely inoffensive, is to mix with it a little charcoal dust, prepared muck, dry earth, or any other good absorbent—thus making what is called poudrette. The mode of doing this must depend on circumstances.

"Several plans have recently been devised which have for their object the improvement of privy accommodations of detached houses. One of these, the 'Earth Closet,' of the Rev. Henry Moule, an English clergyman, is at once so cheap, so simple, and so perfect in its operation, that it should receive general attention. Its action is based on the power of soils which contain clay or organic matter (loam or mould) to absorb all offensive effluvia. This power is so great that not only will a pint of sifted and air-dried earth completely deodorize the matters of a single evacuation, but if dried in the air after each use, the same pint of earth may be used over and over again—losing, apparently, none of its power of absorption—until it finally becomes as powerful a manure as Peruvian guano—although entirely inoffensive to the sight and smell." *

The manure thus made is of the most valuable character, and may be used under any circumstances with a certainty of obtaining a good crop.

For an analysis of human manure see Section V.

HOG MANURE.

Hog manure is very valuable, but it must be used with care. It is very liable to make cabbages *clump-footed*, and to induce a disease in turnips called *anbury* (or fingers and toes). It is so violent in its action that, when applied to crops in a pure state, it

* From an article on Sewers and Earth Closets, in the *American Agricultural Annual*, for 1868, by Geo. E. Waring, Jr.

often produces injurious results. The only precaution necessary is to supply the sty with prepared muck, charcoal-dust, leaf-mould, earth, or any absorbent in plentiful quantities, often adding fresh supplies. The hogs will work this over with the manure; and, when required for use, it will be found an excellent fertilizer. The absorbent will have overcome its injurious tendency, and it may be safely applied to any crop, except cabbages and the smooth-leaved turnips—such as the rutabaga. From the variety and rich character of the food of this animal, his manure is of a superior quality.

Butchers' hogpen manure is one of the best fertilizers known. It is made by animals that live chiefly on blood and other animal refuse, and is very rich in nitrogen and the phosphates. It should be mixed with prepared muck, or its substitute, to prevent the loss of its ammonia, and as a protection against its injurious effect on plants.

POULTRY-HOUSE MANURE.

Next in value to night soil, among domestic manures, are the excrements of poultry, pigeons, etc. Birds live on the nice bits of creation, seeds, insects, etc., and they discharge their solid and liquid excrements together. Poultry-dung is nearly equal in value to Peruvian guano (except that it contains more water), and it deserves to be carefully preserved and judiciously used. It is as well worth one dollar per bushel as guano is worth seventy-five dollars a ton.

Poultry-manure is liable to as much injury from evaporation and leaching as is any other manure, and equal care should be taken (by the same means) to prevent such loss. Good shelter over the roosts, and frequent sprinkling with prepared muck or charcoal-dust, will be amply repaid by the increased value of the manure, and its better action and greater durability in the soil. The principle upon which Moule's Earth Closet is based may be very effectively applied to the poultry-house. All that is necessary is to dig or fork up the earth floor of their lodging-room as often as may be necessary (say once a week), and to rake it daily so as to mix the fresh droppings with the loose earth. In this manner the floor of the poultry-house, for a depth of eight or ten inches, may be made to absorb the droppings of a whole summer so as to entirely prevent offensive smells or disease, while the earth for that depth will be worth many times what it has cost.

The value of this manure should be taken into consideration in calculating the profit of keeping poultry (as indeed with all other stock). It has been observed by a gentleman of much experience, in poultry raising, that the yearly manure of a hundred fowls applied to previously unmanured land would produce *extra* corn enough to keep them for a year. This is probably a large estimate, but it serves to show that this fertilizer is very valuable, and also that poultry may be kept with great profit, if their excrements are properly secured.

The manure of pigeons has been a favorite fertilizer in some countries for more than 2,000 years.

Market gardeners in England attach much value to rabbit-manure.

SHEEP MANURE.

The manure of sheep is less valuable than it would be if so large a quantity of the nitrogen and mineral parts of the food were not employed in the formation of wool. This has an effect on the richness of the excrements, but they are still of very great value as a fertilizer, and should be protected from loss in the same way as stable-manure.

GUANO.

Guano as a manure has become world renowned The worn-out tobacco lands of Virginia, and other fields in many parts of the country, which seemed to have yielded to the effect of an ignorant course of cultivation, and to have sunk to their final repose, have in many cases been revived to the production of excellent crops, and have had their value multiplied many fold by the use of guano. Although an excellent manure, it should not cause us to lose sight of those valuable materials which exist on almost every farm. Every ton of guano imported into the United States is an addition to our national wealth, but every ton of stable-manure, or poultry-dung, or night soil evaporated or carried away in rivers, is equally a *deduction* from our riches. If the imported manure is to really benefit us, we must not allow it to occasion the neglect and consequent loss of our domestic fertilizers.

The Peruvian guano (which is considered the best) is brought from islands off the coast of Peru. The birds which frequent these islands live almost entirely on fish, and drop their excrements here in a climate where rain is unknown, and where, from the dryness of the air, there is but little loss sustained by the manure. It is brought to this country in large quantities, and is an excellent fertilizer, superior even to night soil.

Injudiciously used, Peruvian guano may become a curse to a country instead of a blessing. It stimulates crops to an inordinate growth and causes them, on the poorer soils, to seek out the last available atom of some mineral which it does not in itself supply in sufficient quantity. When this last atom has been sold off in the crop, the power of the guano to produce a crop, to which that mineral is largely necessary, has ceased. It is not the guano, but the *crop* that has exhausted the land. If all its mineral constituents had been judiciously returned, the soil would not be made poorer,—on the contrary, it would be made better by the decomposition of the roots left in the soil. The best way to use guano, is to compost it with other manures or to mix it with fine earth or muck. In either case, its lumps should be crushed to powder, so that it may be evenly distributed through the soil.

The composition of various kinds of guano may be found in the Section on Analysis.

CHAPTER VII.

OTHER ORGANIC MANURES.

The number of organic manures is almost countless. The most common of these have been described in the previous chapters on the excrements of animals. The more prominent of the remaining ones will now be considered. As a universal rule, it may be stated that all organic matter (everything which has had vegetable or animal life) is capable of feeding plants.

DEAD ANIMALS.

The bodies of animals contain much *nitrogen*, as well as large quantities of the phosphates and other inorganic materials required in the growth of plants. On their decay, the nitrogen is resolved into *ammonia*, and the mineral matters become valuable as food for the inorganic parts of plants.

If the decomposition of animal bodies takes place in exposed situations, and without proper precautions, the ammonia escapes into the atmosphere, and much of the mineral portion is leached out by rains. The use of absorbents, such as charcoal-dust, prepared muck, earth, etc., will entirely prevent the evaporation, and will in a great measure serve as a protection against leaching.

If a dead horse be cut in pieces and mixed with ten loads of muck, the whole mass will, in a single season, become a valuable compost. Small animals, such as dogs, cats, etc., may be with advantage buried by the roots of grape-vines, or trees, or composted as above.

BONES.

The *bones* of animals contain phosphate of lime and gelatine. The gelatine is a nitrogenous substance, and produces ammonia on its decomposition. This subject will be treated more fully under the head of "phosphate of lime" in the chapter on mineral manures, where the treatment of bones is considered more directly with reference to the fertilizing value of their earthy parts.

FISH.

In many localities near the sea-shore large quantities of fish are caught and applied directly to the soil. These make excellent manure. They contain much nitrogen, which renders them strongly ammoniacal on decomposition. Their bones consist of phosphate and carbonate of lime; and, being naturally soft, they decompose in the soil with great facility, and become available to plants. The scales of fish contain valuable quantities of nitrogen, etc., all of which are highly useful.

Refuse fishy matters from markets and from the house are well worth saving. These and fish caught for manure may be made into compost with prepared muck, or earth, etc.; and as they putrefy rapidly, they soon become ready for use. They may be added to the compost of stable manure with great advantage.

Fish (like all other nitrogenous manures) should never be applied as a top dressing, unless previously mixed with a good absorbent of ammonia; but should, when used alone, be immediately plowed under to considerable depth, to prevent the evaporation—and consequent loss—of their fertilizing gases.

Within the past few years the manufacture of oil from fish has become a very extensive industry, especially along the coast of New England. The fish are caught in immense quantities and delivered to the factories, where they are first cooked by steaming and then subjected to very heavy pressure, which removes their oil. The solid matter which is left behind, containing the bones, scales, and muscular tissues, is run through a "picker," and sold for manure. It contains all of the fish that is of value for this purpose, in a very concentrated form, and it is easy of application to the soil. It is now sold for about one-third of the value of Peruvian guano, at which price it is a much more economical fertilizer.

WOOLLEN RAGS, ETC.

Woollen rags, hair, waste of woollen factories, etc., contain both nitrogen and phosphate of lime; and, like all other matters containing these ingredients, are excellent manures, but they must be used in such a way as to prevent the escape of their fertilizing gases. They decompose slowly, and are therefore considered a *lasting* manure. Like all *lasting* manures, however, they are *slow* in their effects, and the most advantageous way to use them is to compost them with stable manure, or with some other rapidly fermenting substance, which will hasten their decomposition and render them sooner available.

Rags, hair, etc., thus treated, will in a short time be reduced to such a condition that they may be more immediately used by plants instead of lying in the soil to be slowly taken up. It is better in all cases to have manures act *quickly* and give an immediate return for their cost, than to lie for a long time in the soil before their influence is felt.

Old leather should not be thrown away. It decomposes very slowly, and consequently is of but little value; but, if put at the roots of young trees, it will in time produce appreciable effects.

Tanners' and curriers' refuse, and all other animal offal, including that of the slaughter-house, are well worth attention, as they contain more or less of those two most important ingredients of manures, nitrogen and phosphate of lime.

It is unnecessary to add that, in common with all other animal manures, these substances must be either composted, or immediately plowed under the soil. Horn piths, and horn shavings, if decomposed in compost with substances which ferment rapidly, make very good manure, and are worth fully the price charged for them.

ORGANIC MANURES OF VEGETABLE ORIGIN.

Muck, the most important of the purely vegetable manures, has been already sufficiently described

It should be particularly borne in mind that, when first taken from the swamp, it is often *sour*, or *cold;* but that if exposed for a long time to the air, or if well treated with lime, unleached ashes, the lime and salt mixture, or any other alkali, its acids will be *neutralized* (or overcome), and it becomes a good application to any soil, except peat or other soils already containing large quantities of organic matter.

SPENT TAN-BARK.

Spent tan-bark, if previously decomposed by the use of alkalies, answers all the purposes of prepared muck, but is more difficult of decomposition.

The bark of trees contains a larger proportion of earthy matter than the wood, and much of this, on the decomposition of the bark, becomes available as manure. The chemical effect on the bark, of using it in the tanning of leather, is such as to render it difficult to be rotted by the ordinary means; but by the use of alkalies it may be reduced to the finest condition, and becomes a most excellent manure. Unless tan-bark be composted with lime, or some other alkali, it may produce injurious effects from the *tannic acid* which it still contains. Alkaline substances will neutralize this acid, and prevent it from being injurious.

One great benefit resulting from the use of spent tan-bark, is due to its power of absorbing moisture from the atmosphere. For this reason it is very valnable for *mulching* * young trees and plants when first set out.

SAWDUST AND SOOT.

Sawdust in its natural state is of very little value to the land, but when decomposed, as may be done by the same method as was described for tan-bark, it is of some importance, on account of the carbon that it contains. Its ash, too, which becomes available, contains soluble earthy matter, and in this way it acts as a direct manure. So far as concerns the value of the ash, however, bark is superior to sawdust. Sawdust may be partially rotted by mixing it with strong manure (such as that of the hog-pen), while it acts as a *divisor*, and prevents its too rapid action when applied to the soil. Some kinds of sawdust, such as that from beech-wood, form acetic acid on their decomposition, and these should be treated with, at least, a sufficient quantity of lime to correct the acid.

Soot is a good manure. It contains much carbon, and has, thus far, all of the beneficial effects of charcoal dust. The sulphur, which is one of its constituents, not only serves as food for plants, but, from its odor, affords a good protection against some insects. A handful of soot thrown over a melon vine, or young cabbage plant, will keep away many insects.

Soot contains some ammonia, and as this is in the form of a *sulphate*, it is not volatile, and conse-

* See the glossary at the end of the book.

quently does not evaporate when the soot is applied as a top dressing, which is the almost universal custom.

GREEN CROPS.

Green crops, to plough under, are in many places largely raised, and are always beneficial. The plants most used for this purpose, in this country, are clover, buckwheat, and peas. These plants have very long roots, which they send deep in the soil to draw up mineral matter for their support. This mineral matter is deposited in the plant. The leaves and roots receive carbonic acid very largely from the air, and from the water in the soil. In this manner they obtain their carbon. When the crop is turned under the soil, it decomposes, and the carbon, as well as the mineral ingredients obtained from the subsoil, are deposited in the surface soil, and become of use to succeeding crops. The hollow stalks of the buckwheat and pea help to loosen the soil.

Although green crops are of great benefit, and require but little labor, they do require, as usually managed, that the use of the land and the expense of seeding and cultivation be entirely devoted to the advantage of future crops.

Very nearly the same benefit, especially in the case of clover, would result from the roots alone of a crop which has been cut for hay and again for seed. This at least is the opinion of many who have had much experience, and who believe that, by the decomposition of the roots only of a heavy crop of clover, the soil may be brought to the highest state of fertility of which it is capable. The cropping of the plant causes an increased growth of the roots, and these, when ploughed up, and allowed to decompose in the soil, constitute an excellent manure, acting both chemically and mechanically, and permanently increasing the value of the land.

If the system of cultivation adopted on the farm does not admit of the use of green crops, its condition may be improved, though more expensively and less completely, by the application of swamp muck or leaf mould, and by the use of the subsoil plough, to loosen the lower soil. Except, however, in these comparatively rare cases, where all the land is needed for use every year, and where extensive manuring is adopted, the liberal use of green crops is always to be recommended.

Before closing this chapter, it may be well to remark that there are various other fertilizers, such as the *ammoniacal liquor of gas-houses*, *soapers' wastes*, *bleachers' lye*, *lees of old oil-casks*, *etc.*, which we have not space to consider at length, but which are all valuable as additions to the compost heap, or as applications, in a liquid form, to the soil.

In many cases (when heavy manuring is practised) it may be well to apply organic manures to the soil in a green state, turn them under, and allow them to undergo decomposition in the ground. The advantages of this system are, that the *heat* resulting from the chemical changes, will hasten the growth of plants by making the soil warmer; the carbonic acid formed will have a beneficial chemical action in the soil, and will be directly presented to the roots instead of escaping into the atmosphere: and if the soil be heavy, the decomposing matters will tend to loosen it, and leave it more porous. As a general rule, however, in ordinary farming, where the amount of manure applied is only sufficient for the supply of food to the crop, it is undoubtedly better to have it previously decomposed,—*cooked* as it were, for the uses of the plants,—as they can then obtain the required amount of nutriment as fast as needed.

ABSORPTION OF MOISTURE.

It is often convenient to know the relative power of different manures to absorb moisture from the atmosphere, especially when we wish to manure lands that suffer from drought. The following results are given by C. W. Johnson, in his essay on salt (pp. 8 and 19). In these experiments the animal manures were employed without any admixture of straw.

	PARTS.
1000 parts of horse-dung, dried in a temperature of 100°, absorbed by exposure for three hours to air saturated with moisture, of the temperature of 62°	145
1000 parts of cow-dung, under the same circumstances, absorbed	130
1000 parts pig-dung	120
1000 " sheep "	81

			PARTS.
1000	parts	pigeon-dung	50
1000	"	rich alluvial soil	14
1000	"	fresh tanner's bark	115
1000	"	putrefied "	145
1000	"	refuse marine salt sold as manure	49½
1000	"	soot	36
1000	"	burnt clay	29
1000	"	coal-ashes	14
1000	"	lime	11
1000	"	sediment from salt-pans	10
1000	"	crushed rock salt	10
1000	"	gypsum	9
1000	"	salt	4

Muck is a most excellent absorbent of moisture, when thoroughly decomposed.

DISTRIBUTION OF MANURES.

The following table from Johnson on Manures, will be found convenient in the distribution of manures.

By its assistance the farmer will know how many loads of manure he requires, dividing each load into a stated number of heaps, and placing them at certain distances. In this manner manure may be applied evenly, and calculation may be made as to the amount, per acre, which a certain quantity will supply.

DISTANCE OF THE HEAPS.	NUMBER OF HEAPS IN A LOAD.									
	1	2	3	4	5	6	7	8	9	10
3 yards......	538	269	179	134	108	89½	77	67	69	54
3½ do.......	395	168	132	99	79	66	56½	49½	44	39½
4 do.......	303	151	101	75½	60½	50½	43¼	37¾	33½	30¼
4½ do.......	239	120	79½	60	47¾	39¾	34¼	30	26½	24
5 do.......	194	97	64½	48½	38¾	32¼	27¾	24¼	21½	19¼
5½ do.......	160	80	53½	40	32	26¾	22¾	20	17¾	16
6 do.......	131	67	44¾	33½	27	22½	19¼	16¾	15	13½
6½ do.......	115	57½	38¼	28¾	23	19	16¼	14¼	12¾	11½
7 do.... ..	99	49½	33	24¾	19¾	16½	14	12¼	11	10
7½ do.......	86	43	28¾	21½	17¼	14¼	12¼	10¾	9½	8½
8 do.......	75½	37¾	25¼	19	15¾	12½	10¾	9½	8	7½
8½ do.......	67	33½	22¼	16¾	13½	11¼	9½	8½	7½	6¾
9 do.......	60	30	20	15	12	10	8½	7¾	6¾	6
9½ do.......	53½	26¾	18	13½	10¾	9	7¾	6¾	6	5¼
10 do.......	48½	24¼	16¼	12	9¾	8	7	6	5½	4¾

Example 1.—Required the number of loads necessary to manure an acre of ground, dividing each load into six heaps, and placing them at a distance of 4½ yards from each other. The answer by the table is 39¾.

Example 2.—A farmer has a field containing 5½ acres, over which he wishes to spread 82 loads of dung. Now 82 divided by 5½, gives 15 loads per acre; and by referring to the table, it will be seen that the desired object may be accomplished by making 4 heaps of a load, and placing them 9 yards apart, or by 9 heaps at 6 yards, as may be thought advisable.

CHAPTER VIII.

MINERAL MANURES.

THE second class of manures named in the general division of the subject, in the early part of this section, comprises those of a mineral character.

These manures have four modes of action when applied to the soil.

1st. They furnish food for the mineral part of plants.

2d. They prepare matters already in the soil for assimilation by roots.

3d. They improve the mechanical condition of the soil.

4th. They absorb ammonia.

Some of the mineral manures produce in the soil only one of these effects, and others are efficient in two or more of them.

The principles to be considered in the use of mineral manures are essentially given in the first two sections of this book. It may be well, however, to repeat them briefly in this connection, and to give the *reasons* why any of these manures are needed,—from which we may learn what rules are to be observed in their application.

1st. Those which are used as food by plants. It will be recollected that the *ash* left after burning plants, and which formed a part of their structures, has a certain chemical composition; that is, it consists of alkalies, acids, and neutrals. It was also stated that the ashes of plants of the same kind are always of about the same composition, while the ashes of different kinds of plants may vary materially. Different parts of the same plant too, as we learned, are supplied with different kinds of ash.

For instance, *clover*, on being burned, leaves an ash containing *lime*, as one of its principal ingredients, while the ash of *potatoes* contains more of *potash* than of anything else.

In the second section, (on soils,) we learned that some soils contain everything necessary to make the ashes of all plants, and in sufficient quantity to supply what is required, while other soils are either entirely deficient in one or more ingredients, or contain so little of them in an available condition, that they are unfertile for certain plants.*

The different requirements of different plants is the foundation of the theory of *special manuring ;*

* In all cases in which the constituents of the soil are spoken of in this book, it should be understood as applying not so much to its absolute chemical composition as to the availability of its plant-feeding parts. An atom of potash may be locked up in the inside of a pebble, and be of no more use to the roots of a plant than if it were a hundred miles away, yet a careful chemical analysis would destroy the pebble and weigh its atom of potash. The food of plants in the soil must exist in what Liebig calls "a state of physical combination," that is, coating the outside of its particles ; attached to them by a feeble attraction which is sufficient to prevent their being washed away by the water of rains. but which yields to the feeding action of roots. It is his belief, and the opinion seems well founded, that it is only, or chiefly from materials so placed, that plants derive their food ; and that the constituents of the soil, before they are taken up by roots, must be separated from their firmer relations and exposed on the surfaces of particles, as above stated.

In like manner those elements of manures which are taken up by the plant are first dissolved in water, from which they are absorbed by the particles of the soil,—spread over its interior surfaces, exposed to the action of roots.

Even the ammonia brought from the atmosphere in falling rain, attaches itself in the same way to the interior surfaces of the soil.

which is that on a soil of tolerable fertility we can grow large crops of any particular plant by using such manures as are chiefly required for its ashes, as phosphoric acid for a crop of wheat, for instance, or potash for potatoes or tobacco.

As a universal rule, it may be stated that to render a soil fertile for any particular plant, we must supply it (unless it already contains them) with those matters which are necessary to make the ash of that plant; and, if we would render it capable of producing *all* kinds of plants, it must be furnished with the materials required in the formation of *all kinds of vegetable ashes.*

To carry out this system, however, with much nicety or certainty, would require a more thorough knowledge of the composition of the soil and of the feeding of plants than we yet possess. The only safe rule is, by the use of manures and of thorough cultivation, to make the soil fertile for all crops; and then to keep it fertile by the return of all mineral matters removed in its produce.

A long acquaintance with any field will show its strong and its weak points, and the greatest skill of the farmer should be applied to strengthening its weaker ones and preventing its stronger ones from becoming weaker. In this way the soil may be raised to its highest state of fertility, and be fully maintained in its productive powers.

2d. Those manures which render available the matters already contained in the soil.

Silicic acid, (or sand,) it will be recollected, exists in all soils; but, in its pure state, is not capable of being dissolved, and therefore cannot be used by plants. The alkalies (as has been stated) have the power of combining with it, making compounds, which are called *silicates.* These are readily dissolved by water, and are available in vegetable growth. Now, if a soil is deficient in these soluble silicates, it is well known that grain, etc., grown on it, not being able to obtain the material which gives them strength, will fall down or *lodge;* but, if such measures be taken as will render the sand soluble, the other conditions of fertility being present, the straw will be strong and healthy. Alkalies used for this purpose, come under the head of those manures which develop the natural resources of the soil.

Again, much of the mineral matter in the soil is combined within particles, and is therefore out of the reach of roots. Lime, among other things, has the effect of causing these particles to crumble and expose their constituents to the demand of roots. Therefore, lime has for one of its offices the development of the fertilizing ingredients of the soil.

3d. Those manures which improve the mechanical condition of the soil.

The alkalies, in combining with sand, commence their action on the surfaces of the particles, and roughen them—*rust* them, as it were. This roughening of particles of some soils prevents them from moving among each other as easily as they do when they are smooth, and thus keeps the ground from being compacted by heavy rains, as it is liable to be in its natural condition. In this way, the mechanical texture of the soil is improved.

It has just been said that *lime* causes the pulverization of the particles of the soil; and thus, by making it finer, it improves its mechanical condition.

Some mineral manures, such as plaster and salt, have the power of absorbing moisture from the atmosphere; and this is a mechanical improvement to dry soils.

4th. Those mineral manures which have the power of absorbing ammonia.

Plaster, *chloride of lime*, *alumina* (*clay*), etc., are large absorbents of ammonia, whether arising from the fermentation of animal manures or washed down from the atmosphere by rains.

Having now explained the reasons why mineral manures are necessary, and the manner in which they produce their effects, we will proceed to examine the various deficiencies of soils and the character of various kinds of this class of fertilizers.

CHAPTER IX.

DEFICIENCIES OF SOILS, MEANS OF RESTORATION, ETC.

As will be seen by referring to the analyses of soils on p. 63, they may be deficient in certain ingredients, which it is the object of mineral manures to supply. These we will take up in order, and endeavor to show in a simple manner the best means of managing them in practical farming.

ALKALIES.

POTASH.

Potash is often deficient in the soil. Its deficiency may have been caused in two ways. Either it may not have existed largely in the rock from which the soil was formed, and consequently is equally absent from the soil itself, or it may have once been present in sufficient quantities, and been carried away in crops, without being returned to the soil in the form of manure, until too little remains in an available form for the requirements of fertility.

In either case the deficiency must be made up; it may be supplied by the farmer in various ways. Potash, as well as all the other mineral manures, is contained in the excrements of animals, but not (as is also the case with the others) in sufficient quantities to restore the proper balance to soils where it is largely deficient, nor even to make up for what is yearly removed with each crop, unless that crop (or its equivalent) has been fed to such animals as return *all* of the fertilizing constituents of their food in the form of manure, and this to be all carefully preserved and applied to the soil. In all other cases, it is necessary to apply more potash than is contained in the excrements of the animals of the farm.

Wood ashes is generally the most available source from which to obtain this alkali. The ashes of all kinds of wood contain potash (more or less, according to the kind—see analyses, Section V.) If the ashes are *leached*, much of the potash is removed; and hence, for the purpose of supplying it, they are less valuable than *unleached* ashes. The latter may be made into compost with muck, as directed in a previous chapter, or applied directly to the soil. In either case the potash is available directly to the plant, or is capable of uniting with the silica in the soil to form silicate of potash. Leached ashes contain too little potash to be valuable in the compost, but, from their imperfect leaching, they do contain enough to make them valuable as manure. Neither potash nor any other alkali should ever be applied to animal manures unless in compost with an absorbent, as they cause the ammonia to be thrown off and lost.

Potash sparlings, or the refuse of potash warehouses, is an excellent manure for lands deficient in this constituent.

Feldspar, *kaolin*, and other minerals containing potash, are, in some localities, to be obtained in sufficient quantities to be used for manurial purposes.

Within a comparatively few years, a new fertilizer—of great value to all regions within carrying distance of its place of deposit—has been brought to the notice of farmers near the seaboard. This is the *Green Sand Marl* of New Jersey, which underlies a wide belt extending from the Atlantic Ocean to the Delaware River, having an area of about 900 square miles. It is very largely used in South Jersey, where it has given great value to land that was previously not fit for cultivation. Quite recently, companies have been formed for its shipment to other places near the coast, and it promises to become of great importance wherever it can be cheaply procured.

An analysis of this manure is given in Section V

SODA.

Soda, the requirement of which is occasioned by the same causes as create a deficiency of potash, and all of the other ingredients of vegetable ashes, may be very readily supplied by the use of *common salt* (chloride of sodium), which is about one-half sodium (the base of soda). The best way to use salt is in the lime and salt mixture, previously described, or as a direct application to the soil. If too much salt be given to the soil it will kill any plant. In small quantities, however, it is highly beneficial, and if *six bushels per acre* be sown broadcast over the land, to be carried in by rains and dews, it will not only destroy many insects (grubs and worms), but will prove an excellent manure. Salt acts directly in the nutrition of plants, as a source of necessary chlorine and soda. There is little doubt, however, that its chief value as a manure in most instances arises from the fact that it renders other plant foods more soluble, and assists in preparing them for use. Salt, even in quantities large enough to denude the soil of all vegetation, is never *permanently* injurious. After a time it seems to have the effect of increasing fertility. One peck of salt in each cord of compost will not only hasten the decomposition of the manures, but will kill seeds and all grubs—a very desirable effect. While small quantities of salt in a compost heap are beneficial, too much (as when applied to the soil) is positively injurious, as it arrests decomposition, fairly *pickles* the manures, and prevents them from rotting.

For *asparagus*, which is a marine plant, salt is an excellent manure, and may be applied in almost unlimited quantities, *while the plants are growing*; if used after they have gone to top, it is injurious. Salt has been applied to asparagus beds in such quantities as to completely cover them, and with apparent benefit to the plants. Of course large doses of salt kill all weeds, and thus save labor, and avoid the injury to the asparagus buds which would result from their removal by hoeing. Salt may be used advantageously in any of the foregoing manners, but should always be applied with care. For ordinary farm purposes, it is undoubtedly most profitable to use the salt with lime, and make it perform the double duty of assisting in the decomposition of vegetable matter, and fertilizing the soil.

Soda unites with the silica in the soil, and forms the valuable *silicate of soda*.

Nitrate of soda, or cubical nitre, which is found in South America, is composed of soda and nitric acid. It furnishes both soda and nitrogen to plants, and is an excellent manure.

LIME.

The subject of *lime* is one of most vital importance to the farmer; indeed, so varied are its modes of action and its effects, that some writers have given it credit for everything good in the way of farming, and have gone so far as to say that *all* permanent improvement of agriculture must depend on the use of lime. Although this is far in excess of the truth (as lime cannot plough, nor drain, nor supply anything but *lime* to the soil), its many beneficial effects demand for it the closest attention.

As food for plants, lime is of considerable importance. All plants contain it—some of them in large quantities. It is an important constituent of straw, meadow hay, leaves of fruit-trees, peas, beans, and turnips. It constitutes more than one-third of the ash of red clover. Most soils contain lime enough for the use of plants; in others it is deficient, and must be supplied artificially before they can produce good crops of those plants of which lime is an important ingredient. The amount required for the mere feeding of plants is not large (much less than one per cent.), but lime is often necessary for other purposes; and setting aside, for the present, its feeding action, we will examine its various effects on the mechanical and chemical condition of the soil.

1. It corrects acidity (sourness).

2. It hastens the decomposition of the organic matter in the soil.

3. It causes the mineral particles of the soil to crumble.

4. By producing the above effects, it prepares the constituents of the soil for assimilation by plants.

5. It is *said* to exhaust the soil; but as it does so through its beneficial action in producing larger crops, and only in this way, it is only necessary to return to the soil the other earthy ingredients that the larger crops remove from it.

1. The decomposition of organic matter in the soil, especially if too wet, often produces acids which make the land *sour*, and cause it to produce sorrel and other weeds, and which interfere with the healthy growth of crops. Lime is an *alkali*, and if applied to soils suffering from sourness, it will unite with the acids, and neutralize them, so that they will no longer be injurious.

2. We have before stated that lime is a decomposing agent, and hastens the rotting of muck and other organic matter. It has the same effect on the organic parts of the soil, and causes them to be resolved into the gases and minerals of which they are formed. It has this effect, especially, on organic matters containing *nitrogen*, causing them to produce ammonia; consequently, it liberates this gas from the animal manures in the soil.

3. Various earthy compounds in the soil are so affected by lime that they lose their power of holding together, and crumble, or are reduced to finer particles, while some of their constituents are rendered soluble. This crumbling effect improves the

mechanical as well as the chemical condition of the soil.

4. We are now enabled to see how lime prepares the constituents of the soil for the use of plants.

By its action on the roots, buried stubble, and other organic matter in the soil, it causes them to be decomposed, and to give up their constituents for the use of roots. In this manner the organic matter is prepared for use more rapidly than it would be, if there were no lime present to hasten its decomposition.

By the decomposing action of lime on the mineral parts of the soil (3), they also are placed more rapidly in a useful condition than would be the case, if their preparation depended on the slow action of atmospheric influences.

Thus we see that lime, aside from its use directly as food for plants, exerts a beneficial influence on both the organic and inorganic parts of the soil.

5. Many farmers assert that lime *exhausts* the soil.

If we examine the manner in which it does so, we shall see that this is no argument against its use.

It exhausts the organic parts of the soil by decomposing them, and resolving them into the gases and minerals of which they are composed. The gases arising from the organic matter cannot escape; because there is in all arable soils a sufficient amount of clay and carbonaceous matter present to cause these gases to be retained until required by the roots of plants. Hence, although the organic matter of manure and vegetable substances may be *altered in* *form* by the use of lime, it can escape (except in very poor soils) only as it is taken up by roots to feed the crop, and such exhaustion is certainly profitable, and, so far as the organic parts are concerned, the fertility of the soil will be fully maintained by the decomposition of new roots and of organic manures.

The only way in which lime can exhaust the earthy parts of the soil is, by altering their condition, so that plants can use them more readily. That is, it exposes it to the action of roots. We have seen that fertilizing matter cannot be leached out of a good soil, in any material quantity, nor can it be carried down to any considerable depth. Hence, there can be no loss in this direction; and, as mineral matter cannot evaporate from the soil, the only way in which it can escape is through the structure of plants.

If lime is applied to the soil, and increases the amount of crops grown by preparing for use a larger supply of earthy matter, of course, the removal of earthy substances from the soil will be more rapid than when only a small crop is grown, and the soil will be sooner exhausted,—not by the lime, but by the plants. In order to make up for this exhaustion it is necessary that a sufficient amount of inorganic matter be supplied to compensate for the increased quantity taken away by plants.

Thus we see that it is hardly fair to accuse the *lime* of exhausting the soil, when it only improves its character, and increases the yield. It is the *crop* that takes away the fertility of the soil (the same as would be the case if no lime were used, only faster, because the crop is larger), and in all judicious cultivation this loss will be fully compensated by the application of manures, thereby preventing the exhaustion of the soil.

Kind of lime to be used. The first consideration in procuring lime for manuring land, is to select that which contains but little, if any, *magnesia.* Nearly all stone lime contains more or less of this, but some kinds contain more than others. When magnesia is applied to the soil in too large quantities, it is positively injurious to plants, and care is necessary in making selection. As a general rule, it may be stated, that the best plastering lime makes the best manure. Such kinds only should be used as are known from experiment not to be injurious.

Shell lime is undoubtedly the best of all, for it contains no magnesia, and it does contain a small quantity of *phosphate of lime.* In the vicinity of the sea-coast, and near the lines of railroads, oyster shells, clam shells, etc., can be cheaply procured. These may be prepared for use in the same manner as stone lime.

The preparation of the lime is done by first burning and then slaking, or by putting it directly on the land, in an unslaked condition, after its having been burned. Shells are sometimes *ground*, and used without burning; this is hardly advisable, as they cannot be made so fine as by burning and slaking. As was stated in the first section of this book, lime usually exists in nature, in the form of carbonate of lime, as limestone, chalk, or marble (being lime and carbonic acid combined), and when this is burned the carbonic acid is thrown off, leaving the lime in a pure or caustic form. This is called burned lime, quick-lime, lime-shells, hot lime, etc. If the proper quantity of water be poured on it, it is immediately taken up by the lime, which falls into a dry powder, called *slaked lime.* If *quick-lime* were left exposed to the weather it would absorb moisture from the atmosphere, and become what is termed *air-slaked.*

When *slaked lime* (consisting of lime and water) is exposed to the atmosphere, it absorbs carbonic acid, and becomes carbonate of lime again; but it is now in the form of a very fine powder, and is much more useful than when in the stone, or even when finely ground.

If quick-lime is applied directly to the soil, it absorbs first moisture, and then carbonic acid, becoming finally a powdered carbonate of lime.

One ton of *carbonate of lime* contains 11¼ cwt. of lime; the remainder is carbonic acid. One ton of *slaked lime* contains about 15 cwt. of lime; the remainder is water.

Hence we see that lime should be burned, and not slaked, before being transported, as it would be unprofitable to transport the large quantity of carbonic acid and water contained in carbonate of lime and slaked lime. The quick-lime may be slaked and carbonated after reaching its destination, either before or after being applied to the land.

As has been before stated, much is gained by slaking lime with *salt water*. Indeed, in many cases it will be found profitable to use all lime in this way. Where a direct action on the inorganic matters contained in the soil is desired, it may be well to apply the lime directly in the form of quick-lime; but, where the decomposition of the vegetable and animal constituents of the soil is desired, the correction of *sourness*, or the supplying of lime to the crop, the mixture with salt would be advisable.

The amount of lime required *by plants* is, as was before observed, usually small compared with the whole amount contained in the soil; still it is not unimportant.

			OF LIME.
25 bus. of wheat contain about			13 lbs.
25	"	barley "	10½ "
25	"	oats "	11 "
2 tons of turnips		"	12 "
2	"	potatoes "	5 "
2	"	red clover "	77 "
2	"	red grass "	30 " *

The amount of lime required at each application, and the frequency of those applications, must depend on the chemical and mechanical condition of the soil. No exact rule can be given, but probably the custom of each district—regulated by long experience—is the best guide.

Lime sinks in the soil; and therefore, when

* The straw producing the grain, and the turnip and potato tops, contain more lime than the grain and roots.

used alone, should always be applied as a top dressing to be carried into the soil by rains. The tendency of lime to settle is so great that, when cutting drains, it may often be observed in a whitish streak on the top of the subsoil. After heavy doses of lime have been given to the soil, and have settled so as to have apparently ceased from their action, they may be brought up and mixed with the soil by deeper plowing.

Lime should never be mixed with animal manures, unless in compost with muck or some other good absorbent, as it causes the escape of their ammonia.

PLASTER OF PARIS.

Plaster of Paris or Gypsum (sulphate of lime) is composed of sulphuric acid and lime in combination.

It is a constituent of many plants. It also furnishes them with sulphuric acid, and with the sulphur of which a small quantity is contained in seeds, etc.

It is an excellent absorbent of ammonia, and is very useful to sprinkle in stables, poultry houses, pig-styes, and privies, where it absorbs the escaping gases, saving them for the use of plants, and purifying the air—rendering stables, etc., more healthy than when not so supplied.

CHLORIDE OF LIME.

Chloride of lime contains lime and chlorine. It furnishes both of these constituents to plants, and is an excellent absorbent of ammonia and other gases arising from decomposition—hence its usefulness in destroying bad odors, and in preserving fertilizing matters for the use of crops.

It may be used like plaster, or in the decomposition of organic matters, where it not only hastens decay, but absorbs and retains the escaping gases.

Lime in combination with *phosphoric acid* forms the valuable *phosphate of lime*, of which so large a portion of the ash of grain, and the bones of animals, is formed. This will be spoken of more at length under the head of "phosphoric acid."

MAGNESIA.

Magnesia is a constituent of vegetable ashes, and is almost always present in the soil in sufficient quantities.

ACIDS.

SULPHURIC ACID.

Sulphuric acid is a very important constituent of vegetable ashes. It is sometimes deficient in the soil, particularly where potatoes have been long cultivated. One of the reasons why *plaster* (sulphate of lime) is so beneficial to the potato crop is probably that it supplies it with sulphuric acid.

Sulphuric acid is commonly known by the name of *oil vitriol*, and may be purchased for agricultural purposes at a low price. It may be added in a very dilute form (weakened by mixing it with a large quantity of water) to the compost heap, where it will change the ammonia to a sulphate as soon as formed, and thus prevent its loss, as the sulphate of ammonia is not volatile; and, being soluble in water, is useful to plants. Some idea of the value of this compound may be formed from the fact that manufacturers of manures pay a high price for sulphate of ammonia, to insure the success of their fertilizers. Notwithstanding this, many farmers persist in throwing away hundreds of pounds of *ammonia* every year, as a tax for their ignorance (or negligence), while a small tax in money—not more valuable nor more necessary to their success—for the support of common schools, and the better education of the young, is too often unwillingly paid.

If a tumbler full of sulphuric acid (costing a few cents) be thrown into the tank of the compost heap once a month, the benefit to the manure would be very great.

Care is necessary that *too much* sulphuric acid be not used, as it would prevent the proper decomposition of the manure.

In many instances it will be found profitable to use sulphuric acid in the manufacture of superphosphate of lime (as directed under the head of "phosphoric acid"), thus making it perform the double purpose of preparing an available form of phosphate, and of supplying sulphur and sulphuric acid to the plant.

PHOSPHORIC ACID.

We come now to the consideration of one of the most important of all subjects connected with agriculture.

Phosphoric acid, which forms about one-half of the ashes of wheat, rye, corn, buck-wheat, and oats; nearly the same proportion of those of barley, peas, beans, and linseed; an important part of the ashes of potatoes and turnips; one-quarter of the ash of milk, and a very large proportion of the bones of animals, often exists in the soil in the proportion of only about one or two pounds in a thousand, and but a very small part even of this amount is in a condition to be taken up by roots. The cultivation of our whole country has been such, as to take away the phosphoric acid from the soil without returning it, except in very minute quantities. Every hundred bushels of wheat sold contains (and removes permanently from the soil) about *sixty pounds* of phosphoric acid. Other grains, as well as the root crops and grasses, remove, likewise, a large quantity of it. It has been said by a contemporary writer, that for each cow kept on a pasture through the summer, there is carried off in veal, butter, and cheese, not less than *fifty* lbs. of phosphate of lime (bone-earth) on an average. This would be *one thousand lbs.* for twenty cows; and it shows clearly why old dairy pastures become so exhausted of this substance, that they will often no longer produce those nutritious grasses which are favorable to butter and cheese making.

That this removal of one of the most valuable constituents of the soil has been the cause of more exhaustion of farms, and more emigration, in search of fertile districts, than any other single effect of injudicious farming, is a fact which multiplied instances most clearly prove.

It is stated that the Genesee and Mohawk valleys, which once produced an average of *thirty-five* or *forty bushels* of wheat per acre, have since been reduced, in their average production, less than twenty bushels. Hundreds of similar cases might be stated; and in a large majority of these, could the cause of the impoverishment be ascertained, it would be found to be the removal of the phosphoric acid from the soil.

The evident tendency of cultivation being to continue this ruinous system, and to prey upon the vital strength of the country, it is necessary to take such measures as will arrest the outflow of this valuable material. This can never be fully accomplished until the laws which regulate the nutrition of plants are generally understood and appreciated by the people at large. The enormous waste of the most valuable manures, taking place not only in every city, but about every residence in the land, can only be arrested when the importance of restoring to the soil a full equivalent for what is taken from it is universally realized. China and Japan, the most densely peopled countries in the world, have been cultivated for thousands of years with no diminution of their fertility. Japan is about as large and about as densely peopled as Great Britain, yet while Great Britain imports immense quantities of grain, guano, bones, and other fertilizers, and pours its immense volumes of manure into the sea, Japan neither wastes nor imports. The bread of its people is raised on its fields, which have been cultivated for uncounted ages, while every scrap of fertilizing matter is saved with scrupulous care.

It is true that the processes by which manure is saved and applied in China and Japan are not nice, but it is saved, nevertheless, and the fact that our chemical knowledge enables us to accomplish the same result in an inoffensive manner, should make us all the more earnest in mending our ways.

Many suppose that soils which produce good crops, year after year, are inexhaustible, but time invariably proves the contrary. They may possess a sufficiently large stock of phosphoric acid, and other plant constituents, to last a long time, but when that stock becomes so reduced that there is not enough left for the uses of full crops, the productive power of the soil will yearly decrease, until it becomes worthless. It may last a long time—a century, or even more—but as long as the system is to *remove everything, and return nothing*, the fate of the most fertile soil is certain.

As has been stated already, the constituent of the soil which is most likely to become deficient is *phosphoric acid*. One principal source from which this can be obtained is found in the bones of animals.

These contain a large proportion of *phosphate of* *lime.* They are the receptacles which collect nearly all of the phosphates in crops which are fed to animals, and are not returned in their excrements. For the grain, etc., sent out of the country, there is no way to be repaid except by the importation of this material; but nearly all that is fed to animals may, if a proper use be made of their excrement, and of their bones after death, be returned to the soil. With the treatment of animal excrements we are already familiar, and we will now turn our attention to the subject of

BONES.

Bones consist, when dried, of about one-third organic matter, and two-thirds earthy matter.

The organic matter consists chiefly of *gelatine*—a compound containing *nitrogen.*

The earthy part is chiefly *phosphate of lime.*

Hence we see that bones are excellent, both as organic and as mineral manure. The organic part, containing nitrogen, forms *ammonia*, and the inorganic part supplies the much-needed *phosphoric acid* to the soil.

Liebig says that, as a producer of ammonia, 100 lbs. of dry bones are equivalent to 250 lbs. of human urine.

Bones are applied to the soil in almost every conceivable form. *Whole bones* are often used in very large quantities; their action, however, is extremely slow, and it is never advisable to use them in this form.

Ten bushels of bones, finely ground, will produce larger results, during the ten years after application, than would one hundred bushels merely broken; not because the dust contains more fertilizing matter than the whole bones, but because that which it does contain is in a much more available condition. It ferments readily, and produces ammonia, while the ashy parts are exposed to the action of roots.

It is a rule which is applicable to all manures, that the more finely they are pulverized or divided, the more valuable they become. Not only do they expose much more surface to the feeding action of roots, but from their fine division they can be much more evenly distributed through the soil. If it is true, as seems probable, that the absorptive power of fertile soils is so strong as to prevent dissolved plant food from being carried beyond the point with which it first comes in contact, until the soil about that point has taken up all that it is capable of holding, then the more widely we spread a manure before it is dissolved, the more uniformly rich will be the soil. By sowing coarsely crushed bones, we fertilize the soil *in spots*. By crushing each lump we not only make all of its constituents immediately available, but we make it reach every part of the surface between the spots above referred to. Even Peruvian guano, soluble as it is in water, is much more effective when finely ground before being spread upon the land.

Bone-black. If bones are burned in retorts, or otherwise protected from the atmosphere, their or ganic matter will all be driven off except the carbon, which not being supplied with oxygen cannot escape. In this form bones are called *ivory black*, or *bone black;* and they contain all of the earthy matter and carbon of the bones. The nitrogen having been expelled, it can make no ammonia; and thus far the original value of bones is reduced by burning—that is, a ton of bones contains more fertilizing matter before, than after, burning. This means of pulverizing bones is not to be recommended for the use of farmers, who should not lose the ammonia forming a part of bones, more than that of other manure.

Composting bones with ashes is a good means of securing their decomposition. They should be placed in a water-tight vessel (such as a cask); first, three or four inches of bones, then the same quantity of strong unleached wood ashes, continuing these alternate layers until the cask is full, and keeping them *always wet.* If they become too dry they will throw off an offensive odor, accompanied by the escape of ammonia, and consequent loss of value. In about one year, the whole mass of bones (except, perhaps, those at the top) will be softened, so that they may be easily crushed, and they are in a good condition for application to the land. The ashes are, in themselves, valuable, and this compost is excellent for many crops, particularly for Indian corn. A little dilute sulphuric acid, occasionally sprinkled on the upper part of the matter in the cask, will prevent the escape of the ammonia.

Boiling bones under pressure, whereby their gelatine is dissolved away, and the earthy matter left in an available condition, from its softness, is a very good way of rendering them useful; but it requires the use of a steam boiler, and other expensive apparatus.

SUPER-PHOSPHATE OF LIME.

Super-phosphate of lime is made by treating phosphate of lime, or the ashes of bones, with *sulphuric acid.*

Phosphate of lime, as it exists in bones, consists of one equivalent of phosphoric acid and three equivalents of lime.

The word " equivalent " is here used to represent what in chemistry is known as the combining proportion of each element of a compound body—that is, one pound of one substance combines with one and one-half pounds of another, and these proportions are invariable.

In bone earth, or phosphate of lime, one equivalent, or 72 lbs. of phosphoric acid combines with three equivalents (of 28 lbs. each), or 84 lbs. of lime. Now, by adding to this compound one equivalent (or 40 lbs.) of sulphuric acid, we cause one equivalent (28 lbs.) of the lime to be taken away, leaving the 72 lbs. of phosphoric acid combined with only 56 lbs. of lime. By using two equivalents of sulphuric acid (or 80 lbs.) we cause the removal of 56 lbs. of lime, leaving only 28 lbs. combined with the 72 lbs. of phosphoric acid. This is super-phosphate of lime, which is readily soluble in water. It is united with 80 lbs. of sulphuric acid and 56 lbs. of lime in combination with each other, forming 136 lbs. of sulphate of lime, or plaster-of-paris.

The whole compound contains:

Phosphoric acid...............	72 lbs.
Sulphuric acid...............	80 "
Lime........................	84 "
In all..................	236 "

—or, $25\frac{18}{100}$ per cent. of phosphoric acid.

The phosphoric acid, now in combination with only one equivalent of lime, is readily dissolved in water, and will be evenly distributed in the soil; but it will take the earliest opportunity to combine with two more equivalents of lime in the soil, and will again become insoluble. It may well be asked, What is the advantage of making it soluble if it is so soon again to become insoluble?

The answer to this question is clearly stated in the following quotation from Prof. S. W. Johnson's Essays on Manures:—

"This white cloud is precipitated bone-phosphate of lime, and does not essentially differ from the original bone-phosphate, except that it is inconceivably finer than can be obtained by any mechanical means. The particles of the finest bone-dust will not average smaller than one-hundredth of an inch, while those of the precipitated phosphate are not more than one twenty-thousandth of an inch in diameter. Since the particles of the precipitated phosphate are so very much smaller than those of the finest bone-dust, we can understand that their action as a manure would be correspondingly more rapid."

In saying that the phosphate of lime is insoluble, it is meant that it is insoluble in pure water. Water which contains either carbonic acid, ammonia, or common salt (and all soil water contains one or more of these), has the power of dissolving it, and making it available to roots. The action is slow, but it is sufficient, and it is the more rapid the finer the pulverization of the phosphate. The fine precipitated phosphate exposes much more surface to the action of the water, and can consequently be taken up much more rapidly.

Super-phosphate of lime may be made from whole bones, bone-dust, bone-black, or from the pure ashes of bones, or from phosphatic guano.

The reason why super-phosphate of lime is better than phosphate, is therefore easily explained. The *phosphate* is very *slowly* soluble in water, and consequently furnishes food to plants slowly. A piece of bone as large as a pea may lie in the soil for years without being all consumed; consequently, it will be years before its value is returned, and it pays no interest on its cost while lying there. The *super-phosphate* is very rapidly dissolved, and if evenly spread is diffused by the water of rains throughout the soil,—coating its absorbent particles with a nutriment held in a state of physical combination, ready to be yielded to the action of roots; hence its much greater value as a manure.

It is true that the phosphate is a more *lasting* manure than the super-phosphate—in the same way that gold buried in a pot in the garden is more lasting than if used in labor and manure for its cultivation. I desire, once for all, to caution farmers against attaching too much imporance to the *lasting* qualities of a manure. Generally they are *lasting* only in proportion as they are lazy. In manuring, as in other things, a nimble sixpence is better than a slow shilling.

Of course it is not to be understood that all manures used had better exert their full effect on the first year's crop, but the more rapidly it can be made available consistently with the course of cultivation adopted (the rotation, etc.), the less we shall lose in the item of *interest*. A hundred pounds of coarsely ground bones may give an extra crop of 250 lbs. of hay per year for ten years. The same quantity finely ground and evenly spread might add a thousand lbs. to the first year's crop, and if the hay is consumed on the farm, and its constituents returned in the form of manure, the same increase might be received year after year. Therefore, in considering the value of manure, more attention should be given to the rapidity of its action than to the time that it will last. Many farmers who have the proper facilities, may find it expedient to purchase bones or bone-dust and sulphuric acid, and to manufacture their own super-phosphate of lime; others will prefer to purchase the prepared manure. Such purchases should be made with great care, and only from persons of established reputation, for nothing is easier than the adulteration of this material. It is best, always, to stipulate that the manure shall contain a certain percentage of soluble and insoluble phosphoric acid,—and to withhold payment until an average sample of the manure received has been tested by a competent chemist.

SILICIC ACID.

Silicic acid (or sand) always exists in the soil in sufficient quantities for the supply of food for plants; but not always in the proper condition. This subject has been so often explained to the reader of this book, that it is only necessary to repeat here, that when the weakness of the straw or stalk of plants grown on any soil indicates an inability in that soil to supply the silicic acid required for strength, not more sand should be added, but *alkalies*, to combine with the sand already contained in it, and make *soluble silicates* which are available to roots.

Sand is often necessary to stiff clays, as a *mechanical* manure, to loosen their texture and render them easier of cultivation, and more favorable to the distribution of roots, and to the circulation of air and water, and in this capacity it is often very important. In my own practice I find it profitable to haul it three miles to use on heavy clay land.

NEUTRALS.

CHLORINE.

Chlorine, a necessary constituent of plants, and sometimes, though not usually, deficient in the soil, may be applied in the form of salt (chloride of sodium), or chloride of lime. The former may be dissolved in the water used to slake lime, and the latter may, with much advantage, be sprinkled around stables and other places where fertilizing gases are escaping, and, after being saturated with ammonia, applied to the soil, thus serving a double purpose. On a stock farm, a very good way to return to the soil the chlorine contained in the produce sold, is to give it freely to the animals.

OXIDE OF IRON.

Probably all soils contain sufficient quantities of *oxide of iron*, or iron rust, so that this substance can hardly be required as a manure.

Some soils, however, contain the *prot*oxide of iron in such quantities as to be injurious to plants,—see page 74. When this is the case, it is necessary to plow the soil thoroughly, and use such other mechanical means as shall open it to the admission of air. The *prot*oxide of iron will then take up more oxygen, and become the *per*oxide—which is not only inoffensive, but is conducive to fertility.

OXIDE OF MANGANESE.

This can hardly be called an essential constituent of plants, and is never taken into consideration in manuring lands.

VARIOUS OTHER EARTHY MANURES.

LEACHED ASHES.

Among the earthy manures which have not yet been mentioned,—not coming strictly under any of the preceding heads,—is the one known as *leached ashes.*

These are, of course, much less valuable than ashes from which the potash has not been leached out; still, as potash is generally made, the leaching is not very complete, and a considerable quantity of this substance, available to plants, is left in them. In addition to this, they contain some phosphoric acid and silicic acid, which add to their value. Practically, they are held in high esteem in all localities where they can be obtained at a moderate cost of transportation. Care, however, should be taken, not to purchase ashes which have been made in lime-kilns, as these generally contain a large quantity of lime, which is not worth so high a price as the ashes.

OLD MORTAR.

Old mortar is a valuable manure, because it contains not only lime, but compounds of nitric acid with alkalies,—called *nitrates.*

These are slowly formed in the mortar by the changing of the nitrogen of the hair (in the mortar) and of the ammonia received from the atmosphere into nitric acid, and the union of this with the *lime* of the plaster, or with other alkalies which it may contain in minute quantities.

The lime contained in the mortar may be useful in the soil for the many purposes accomplished by other lime, and is generally more valuable than that fresh from the kiln.

GAS HOUSE LIME, ETC.

The refuse lime of gas works, where it can be cheaply obtained, may be advantageously used as a manure. It consists, chiefly, of various compounds of sulphur and lime. It should be composted with earth or refuse matter, so as to expose it to the action of air. It should never be used fresh from the gas house. In a few months the sulphur will have united with the oxygen of the air, and become sulphuric acid, which unites with the lime and makes sulphate of lime (plaster,) which form it must assume, before it is of much value. Having been used to purify gas made from coal, it contains a small quantity of ammonia, which adds to its value. It is considered a profitable manure in England, at the price there paid for it (forty cents a cartload), and, if of good quality, it may be worth more than that, especially for soils deficient in sulphuric acid or lime, or for such crops as are much benefited by plaster. Its price must, of course, be regulated somewhat by the price of lime, which constitutes a large proportion of its fertilizing parts. The offensive odor of this compound renders it a good protection against many insects, when used in its fresh state; but in this state it should be very cautiously applied.

The refuse *liquor of gas works* contains enough ammonia to make it a valuable manure. It should be filtered through earth or muck, which will retain its valuable parts, and will be enriched by them.

SOAPERS' LEY AND BLEACHERS' LEY.

The refuse ley of soap factories and bleaching establishments contains greater or less quantities of soluble silicates and alkalies (especially soda and potash,) and is a good addition to the tank of the compost heap, or it may be used directly as a liquid application to the soil, or, better, filtered as above described. The soapers' ley, especially, will be found a good manure for lands on which grain lodges.

Much of the benefit of this manure arises from the soluble silicates it contains, while its nitrogenous matter obtained from those parts of the fatty matters which cannot be converted into soap, and consequently remain in this solution, forms a valuable addition. Heaps of soil saturated with this liquid in autumn, and subjected to the freezings of winter, form an admirable manure for spring use.

IRRIGATION.

Irrigation, strictly speaking, should not be considered under the head of earthy manures alone, as it often supplies ammonia and other organic matters to the soil. Its chief value, however, in most cases, must depend on the amount of mineral matter which it furnishes.

The word "irrigation" means simply *the act of watering.* In many districts water is in various ways made to overflow the land, and is removed or withheld when necessary for the purposes of cultivation. All river and spring water contains some impurities, many of which are beneficial to vegetation. These are derived from the earth over, or through, which the water has passed. Ammonia also is absorbed by the water from the atmosphere. When water is made to cover the earth, especially if its rapid motion be arrested, much of this fertilizing matter settles, and is deposited on or absorbed by the soil. The water which sinks into the soil carries its impurities to be retained for the uses of plants. When, by the aid of under-drains, or the open texture of the land, the water passes *through* the soil, its impurities are arrested, and become available in vegetable growth. It is, of course, impossible to say exactly what kind of mineral matter is supplied by the water of irrigation, as that depends on the kind of rock or soil from which the impurities are derived; but, whatever it may be, it is generally soluble and ready for immediate use by plants, and is distributed in the most uniform manner possible.

Water which has run over the surface of the earth contains both ammonia and mineral matter, while that which has arisen out of the earth, contains usually only mineral matter. The direct effect of the water of irrigation as a solvent and distributer of the mineral ingredients of the soil, constitutes one of its main benefits.

To describe the many modes of irrigation would be too long a task for our limited space. It may be applied in any way in which it is possible to cover the land with water, at stated times. Care is necessary, however, that it does not wash more fertilizing matter away from the soil than it deposits upon it, as would often be the case, if a strong current of water were run over it. Brooks may be dammed up, and thus made to cover a large quantity of land. In such a case the rapid current would be destroyed, and the fertilizing matter would settle; but, if the course of the brook were turned, so that it would run in a current over any part of the soil, it might carry away more than it deposited, and thus prove injurious. Small streams turned on to land, from the washing of roads, or from elevated springs, are good means of irrigation, and produce increased fertility, except where the soil is of such a character as to prevent the water from passing away, in which case it must first be under-drained.

Irrigation was one of the oldest sources of fertility used by man, and still continues in great favor wherever its effects have been witnessed. In England and Scotland, much attention is now being paid to the question of liquid manure irrigation, and an attempt is being made to employ the vast discharges of the London sewers. For this purpose it is in con templation to build an aqueduct forty miles long and nine feet in diameter for its distribution. In the experiments made with this manure during the summer of 1867, fifty-three tons of Italian rye-grass were grown on a single acre, nine tons being grown in twenty-two days.

On the farm of the celebrated Mr. Mechi at Tiptree Hall, the system was, many years ago, adopted of converting all the manure of the stables into a liquid, and distributing it over the farm by means of under-ground pipes and movable hose. Mr. Mechi still continues the practice and considers it profitable.

This subject is mentioned in this connection, not as affording an example which can be profitably followed here, so much as because it shows how much expense may be profitably applied to the distribution of manure in a liquid form.

MIXING SOILS.

The *mixing of soils* is often all that is necessary to render them fertile, and to improve their *mechanical* condition. For instance, soils deficient in potash, or any other constituent, may have that deficiency supplied, by mixing with them soil containing this constituent in excess.

It is very frequently the case, that such means of improvement are easily availed of. While these chemical effects are being produced, there may be an equal improvement in the mechanical character of the soil. Thus stiff clay soils are rendered lighter, and more easily workable, by an admixture of sand, while light blowy sands are compacted, and made more retentive of manure, by a dressing of clay or of muck. Of course, this cannot be depended on as a sure means of chemical improvement, but in a majority of cases the land will be benefited by mixing with it soil of a different character. It is not always necessary to go to other locations to procure the earth to be applied, as the sub-soil is often very different from the surface soil, and simple deep plowing will suffice, in such cases, to produce the required admixture, by bringing up the earth from below to mingle it with that of a different character at the surface.

Until it is demonstrated that a large admixture of the sub-soil will not lessen the fertility of the surface (and in a large majority of cases it will not), it is safest to deepen the plowing inch by inch. This subject is worthy of the consideration of all farmers, for there are very few cases in which the arable surface will not be improved by the addition of matters contained in the sub-soil. Even the earth thrown from the bottom of deep ditches sometimes has an astonishing effect on the fertility of the soil, and it would be well to try the experiment of digging a deep pit, spreading the earth taken from it on the surface of the land. If this is found to have a good effect, it will offer a ready means of improving the soil.

In the foregoing remarks on the subject of mineral manures, I have endeavored to point out such a course as would result in the "greatest good to the greatest number," and consequently, have neglected much which might discourage the farmer with the idea, that the whole system of scientific agriculture is too expensive for his adoption. Still, while I have confined my remarks to the more simple improvements on the present system of management, I would say briefly, that *no manuring can be strictly economical that is not based on a knowledge of the requirements of the soil and of the crops, and of the best means of supplying them, together with the most scrupulous care of every ounce of evaporating or soluble manure made on the farm, and a return of the earthy matters sold off in produce.*

CHAPTER X.

ATMOSPHERIC FERTILIZERS.

It is not common to regard the gases in the atmosphere in the light of manures, but they are the most important manures we have, as they are the original source of more than nine-tenths of the entire production of our fields. Indeed, they are almost the only organic manure ever received by the uncultivated parts of the earth, as well as by a large portion of that which is occupied in the production of food for man.

If these gases were not manures; if there were no means by which they could be used by plants, the fertility of the soil would long since have ceased, and the earth would be unfertile. That this must be true, will be shown by a few moments' reflection on the facts stated in the first part of this book. The fertilizing gases in the atmosphere being composed of the constituents of decayed plants and animals, it is as necessary that they should be again returned to the form of organized matter, as it is that constituents taken from the *soil* should not be put out of existence.

AMMONIA.

The *ammonia* in the atmosphere probably cannot be appropriated by the leaves of plants, and must, therefore, enter the soil to be assimilated by roots. It reaches the soil in two ways. It is either arrested from the air circulating through the soil, or it is absorbed by rains in the atmosphere, and thus carried to the earth, where it is retained by its clay and carbon, for the uses of plants. In the soil, ammonia is the most important of all *organic* manures. In fact, the value of the organic parts of manure may be estimated, either by the amount of ammonia which they will yield, or by their power of absorbing ammonia from other sources.

The most important use of ammonia in the soil is to supply *nitrogen* to plants ; but it has other offices which are of consequence. It assists in some of the chemical changes necessary to prepare the matters in the soil for assimilation, and gives to the water in which it is dissolved an increased power to dissolve mineral plant food.

Although, in the course of nature, the atmospheric fertilizers are largely supplied to the soil, without the immediate attention of the farmer, it is not beyond his power to cause their absorption in still greater quantity. The means for doing this have been repeatedly given in the preceding pages, but it may be well to name them again in this chapter.

The condition of the soil is the main point to be considered. It must be such as to absorb and retain ammonia—to allow water to pass *through* it, and be discharged *below* the depth to which the roots of crops are searching for food—and to admit of a free circulation of air.

The power of absorbing and retaining ammonia is not possessed by sand, but it is a prominent property of clay, charcoal, and some other matters named as absorbents. Hence, if the soil consist of pure sand, it will not make use of the ammonia brought to it from the atmosphere, but will allow it to evaporate immediately after a shower, or to be washed through it by rains. Soils in this condition require additions of absorbent matters, to enable them to use the ammonia received from the atmosphere. Soils already containing a sufficient amount of clay or charcoal, are thus far prepared to receive benefit from this source.

The next point is to cause the water of rains to pass *through* the soil. If it lies on the surface, or runs off without entering the soil, it is not probable that the fertilizing matters which it contains will all be abstracted. Some of them will undoubtedly return to the atmosphere on the evaporation of the water; but, if the soil contains a sufficient supply of absorbents, and will allow all rain water to pass through it, the fertilizing gases will all be retained. They will be filtered out of the water, which will pass out of the drains almost pure.

This subject will be more fully treated in Section IV., in connection with under-draining.

Besides the properties just described, the soil ought to possess the power of admitting a free circulation of air. To effect this, the soil should be well pulverized to a great depth. If, in addition to this, it be of such a character as to allow water to pass through it, it will facilitate such a circulation of air as is best calculated to give the greatest supply of ammonia.

CARBONIC ACID.

Carbonic acid is received from the atmosphere, both by the leaves and by the roots of plants.

It is absorbed by the water in the soil, and greatly increases its power of dissolving earthy plant food. This use is one of very great importance, as it is equivalent to making the minerals themselves more soluble. Water dissolves carbonate of lime, etc., exactly in proportion to the amount of carbonic acid which it contains. We should, therefore, strive to have as much carbonic acid as possible in the water in the soil. One way, in which to effect this, is to admit to the soil the largest possible quantity of atmospheric air, which contains this gas.

The condition of soil necessary for this, is the same as is required for the deposit of ammonia by the same circulation of air.

OXYGEN.

Oxygen, though not taken up by plants as food in its pure form, may justly be classed among manures, if we consider its effects both chemical and mechanical in the soil.

1. By oxidizing or *rusting* some of the constituents of the soil, it prepares them for the uses of plants.

2. It unites with the *prot*oxide of iron, and changes it to the *per*oxide.

3. If there are *acids* in the soil, which make it sour and unfertile, it may be opened to the circulation of the air, and the oxygen will prepare some of the mineral matters contained in the soil to unite with the acids and neutralize them.

4. Oxygen combines with the carbon of organic matters in the soil, and causes them to decay. The combination produces carbonic acid.

5. It undoubtedly affects in some way the matter which is thrown out from the roots of plants. This,

if allowed to accumulate, and remain unchanged, is supposed to be injurious to plants; but, probably, the oxygen and carbonic acid of the air in the soil change it to an inoffensive form, and even make it again useful to the plant.

6. It may also improve the *mechanical* condition of the soil, as it causes its particles to crumble, thus making it finer; and it roughens the surfaces of particles, making them less likely to become too compact.

These properties of oxygen claim for it a high place among the atmospheric fertilizers.

WATER.

Water may be considered an atmospheric manure, as its chief supply to vegetation is received from the air in the form of rain or dew. Its many effects are already too well known to need further comment.

Supplying water to the soil by the deposit of *dew* will be considered in Section IV.

CHAPTER XI.

RECAPITULATION.

MANURES have two distinct classes of action in the soil, namely, *chemical* and *mechanical*.

Chemical manures are those which enter into the construction of plants, or produce such chemical effects on matters already contained in the soil as shall prepare them for use.

Mechanical manures are those which improve the mechanical condition of the soil, such as loosening stiff clays, compacting light sands, pulverizing large particles, etc. Many manures act both chemically and mechanically.

Manures may be classified under three distinct heads, namely, *Organic*, *mineral*, and *atmospheric.*

Organic manures comprise all vegetable and animal matters (except ashes) which are used to fertilize the soil. Vegetable manures supply carbonic acid, some ammonia, and earthy matter to plants. Animal manures supply the same substances and much more ammonia.

Mineral manures comprise ashes, salt, phosphate of lime, plaster, etc. They supply plants with earthy matter. Their usefulness depends in great degree on their solubility.

Many of the organic and mineral manures have the power of absorbing ammonia arising from the decomposition of animal manures, as well as that which is brought to the soil by rains—these are called *absorbents.*

Atmospheric manures consist of ammonia, carbonic acid, oxygen and water. Their greatest usefulness requires the soil to allow the water of rains to pass *through* it, to admit of a free circulation of air among its particles, and to contain a sufficient amount of absorbent matter to arrest and retain all ammonia and carbonic acid presented to it.

Manures should be applied to the soil with due regard to its requirements.

Ammonia and carbon are always useful, but mineral manures become mere *dirt* when applied to soils already containing them in abundance.

Organic manures must be protected against the escape of their ammonia, and especially against the leaching out of their soluble parts. One cord of stable manure properly preserved, is worth ten cords which have lost all of their ammonia by evaporation, and their soluble parts by leaching—as is the case with much of the manure kept exposed in open barn-yards.

Atmospheric manures cost nothing, and are of great value when properly employed. In consequence of this, the soil which is enabled to make the largest appropriation of the atmospheric fertilizers, is worth many times as much as that which allows them to escape.

In fact, it may be considered to be the object of all cultivation, to use the advantages which the soil and manures offer for the purpose of consolidating and giving a useful form to the carbonic acid, ammonia and water, which are freely offered to all seekers.

Liebig says:—"A certain mass of gold and silver circulates in the world, and the art of becoming rich consists in knowing the way to divert from the main stream an additional brook to one's own house. In like manner there circulates, in the air and in the soil, a relatively inexhaustible quantity of the food of plants; and the art of the farmer consists in knowing and using the means of rendering this food available for his crops. The more he is able to divert from the moving stream (the air) to the immovable promoter of his production (the soil of his fields), the more will the sum of his wealth and his products increase."

SECTION FOURTH.

MECHANICAL CULTIVATION.

SECTION FOURTH.

MECHANICAL CULTIVATION.

CHAPTER I.

THE MECHANICAL CHARACTER OF SOILS.

The mechanical character of the soil has been sufficiently explained in the preceding remarks, and the learner knows that it has many offices to perform aside from the feeding of plants.

1. It admits the roots of plants, and holds them in their position.

2. By a sponge-like action, it holds water for the uses of the plant.

3. It absorbs moisture from the atmosphere to supply the demands of the plants.

4. It absorbs heat from the sun's rays to assist in the processes of growth.

4. It admits air to circulate among roots, and supply them with a part of their food, while the oxygen

of that air renders available the minerals of the soil; and its carbonic acid, being absorbed by the water in the soil, gives it the power of dissolving and supplying to roots more earthy matter than would be dissolved by purer water.

All of these actions the soil must be capable of performing, before it can be in its highest state of fertility. There are comparatively few soils now in this condition, but there are also few which could not be profitably rendered so, by a judicious application of the various modes of cultivation.

The three great objects to be accomplished are:—

1. To adopt such a system of drainage as will cause as much as possible of the water of rains to pass *through* the soil, instead of evaporating from the surface.

2. To pulverize the soil to a considerable depth.

3. To darken its color, and to render it capable of absorbing atmospheric fertilizers.

The means used to secure these effects are *under-draining, sub-soil and surface-plowing, digging, applying muck, etc.*

CHAPTER II.

UNDER-DRAINING.

All soils which are cultivated should be thoroughly underdrained, either naturally or artificially.

All lands which are made wet by springs or through which the water of rains does not readily settle away, must be drained artificially before they can be cultivated to the best advantage.

The advantages of *under*-drains over *open*-drains are very great.

When open drains are used, much water passes into them immediately from the surface, and carries with it fertilizing parts of the soil, while their beds are often puddled by the running water and baked by the heat of the sun, so that they become water tight, and do not admit water from the lower parts of the soil.

The sides of these drains are often covered with weeds, which spread their seeds throughout the whole field. Open drains are not only a great obstruction to the proper cultivation of the land, but they cause much waste of room, as we can rarely plow nearer than within six or eight feet of them.

There are none of these objections to the use of under-drains, as these are completely covered, and do not at all interfere with the cultivation of the surface.

Under-drains may be made with brush, stones, or tiles. Brush is a very poor material, and its use is hardly to be recommended, except when a better material cannot be afforded. Small stones are better, and if these be placed in the bottom of the trenches, to a depth of eight or ten inches, and covered with a little litter, having the earth packed well down on them, they make very good drains. But they are very much more costly than tile drains, and are not so permanent.

TILE DRAINING.

The best under-drains are those made with tiles, or burnt clay pipes. The first form of these used was that called the *horse-shoe tile*, which has the form of an arch, leaving the unprotected ground for the water to flow over; this was superseded by the *round pipe*, and the *sole tile.*

"Experience in both public and private works in this country, and the cumulative testimony of English and French engineers, have demonstrated that the only tile which it is economical to use, is the *best* that can be found, and that the best,—much the best,—thus far invented, is the *pipe, or round tile, and collar;*

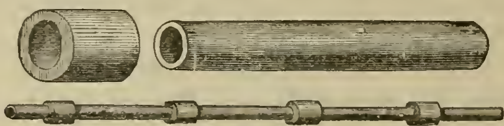

FIG. 3.—Round Tile and Collar.

and these are unhesitatingly recommended for use in all cases. Round tiles of small sizes should not be laid without collars, as the ability to use these constitutes their chief advantage; holding them perfectly in place, preventing the rattling in of loose dirt in laying, and giving twice the space for the entrance of water at the joints. A chief advantage of the larger sizes is, that they may be laid on any side and thus made to fit closely. The usual sizes of these tiles are $1\frac{1}{4}$ inches, $2\frac{1}{4}$ inches, and $3\frac{1}{2}$ inches in interior diameter. Sections of the $2\frac{1}{4}$ inch make collars for the $1\frac{1}{4}$ inch, and sections of the $3\frac{1}{2}$ inch make collars for the $2\frac{1}{4}$ inch. The $3\frac{1}{2}$ inch does not need collars, as it is easily secured in place, and is only used when the flow of water would be sufficient to wash out the slight quantity of foreign matters that might enter at the joints." *

FIG. 4—Sole Tile.

This tile is made (like the horse-shoe and pipe tile) of common brick clay, and is burned the same as bricks. It is about one half or three quarters of an inch thick. The orifice through which the water passes is egg-shaped, having its smallest curve at the bottom. This shape is the one most easily kept clear, as any particles of dirt which get into the drain must fall immediately to the point where even the smallest stream of water runs, and are thus removed. An orifice of about two inches rise is sufficient for the smaller drains, while the main drains require larger tiles.

These tiles are so laid that their ends will touch each other, on the bottoms of the trenches, and are kept in position by having the earth tightly packed

* Draining for Profit and Draining for Health, by G. E. Waring, Jr. page 81.

around them. Care must be taken that no space is left between the ends of the tiles, as dirt would be liable to get in and choke the drain. This may be best prevented by the use of *collars;* but if sole tiles are used, as collars cannot be fitted to them, it is well to cover the top of the joint with a very small rope of twisted grass, secured by a stone or lump of clay on each end, or to lay on the joint a saddle of bent tin, zinc, or galvanized iron, which may be obtained at little cost from a tinsmith, cut from pieces in the waste-heap.

The ditches for tile draining may be narrowed in, at the bottom, to a width barely sufficient for the workman's foot. In filling-in, after the tile is laid, care should be taken that no stones large enough to break the tile be allowed to fall upon them. After the tiles are covered to a depth of a foot or eighteen inches, the filling should be trodden, or pounded, firmly down, so as to fit closely around the tiles, and leave no space for water to circulate about them.

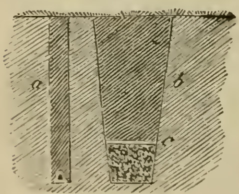

FIG. 5.
a—Tile drain trench.
b—Stone drain trench.
c—Sod laid on the stone.

Tile drains are made with much less labor than the stone drains, as they require less digging, while the breaking up of the stone for the stone drain will be usually more expensive than the tiles. Drains made with large stones are not nearly so good as with small ones, because they are more liable to be choked up by animals working in them.

CHAPTER III.

ADVANTAGES OF UNDER-DRAINING.

The advantages of under-draining are many and important.

1. It greatly lessens the injurious effects of drought.
2. It admits an increased supply of atmospheric fertilizers.
3. It warms the lower portions of the soil.
4. It hastens the decomposition of roots and other organic matter.
5. It accelerates the disintegration of the minerals in the soil.
6. It causes a more even distribution of nutritious matters among those parts of soil traversed by roots.
7. It improves the mechanical texture of the soil.
8. It tends to prevent grasses from "running out."
9. It enables us to deepen the surface soil.

By removing excess of water—

10. It renders soils earlier in the spring.
11. It greatly lessens the throwing out of grain in winter.
12. It allows us to work sooner after rains.
13. It keeps off the effects of cold weather longer in the fall.
14. It prevents the formation of *acetic* and other organic acids, which induce the growth of sorrel and similar weeds.
15. It hastens the decay of vegetable matter, and

the finer comminution of the earthy parts of the soil.

16. It prevents, in a great measure, the evaporation of water, and the consequent cooling of the soil.

17. It admits fresh quantities of water from rains, etc., which are always more or less imbued with the fertilizing gases of the atmosphere, to be deposited among the absorbent parts of soil, and given up to the demands of plants.

18. It prevents the formation of so hard a crust on the surface of the soil as is customary on heavy lands.

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1. Under-draining *lessens the effect of drought*, because it gives a better circulation of air in the soil (it does so by making it more open). There is always the same amount of water *in* and *about* the surface of the earth. In winter there is more in the soil than in summer, while in summer, that which has been dried out of the soil exists in the atmosphere in the form of a *vapor*. It is held in the vapory form by *heat*, which acts as *braces* to keep it distended. When vapor comes in contact with substances sufficiently colder than itself, it gives up its heat—thus losing its braces—contracts, and becomes liquid water.

This may be observed in hundreds of common operations.

It is well known that a cold pitcher in summer robs the vapor in the atmosphere of its heat, and causes it to be deposited on its own surface. It looks as though the pitcher were *sweating*, but the water all comes from the atmosphere, not, of course, through the sides of the pitcher.

If we breathe on a knife-blade, it condenses in the same manner the moisture of the breath, and becomes covered with a film of water.

Stone houses are damp in summer, because the inner surfaces of the walls, being cooler than the atmosphere, cause its moisture to be deposited in the manner described. By leaving a space, however, between the walls and the plaster, this moisture is prevented from being troublesome, and if the space is closed against the circulation of air containing moisture there will be no vapor brought in contact with the cool surface of the wall, and therefore no deposit of moisture.

Nearly every night in the summer season, the cold earth receives moisture from the atmosphere in the form of dew.

A cabbage, which at night is very cold, condenses water to the amount of a gill or more.

The same operation takes place in the soil. When the air is allowed to circulate among its lower and *cooler* particles, they receive moisture from the same process of condensation. Therefore, when, by the aid of under-drains, the lower soil becomes sufficiently open to admit of a circulation of air, the deposit of atmospheric moisture will keep the soil supplied with water at a point easily accessible to the roots of plants.

If we wish to satisfy ourselves that this is *practi cally* correct, we have only to prepare two boxes of finely pulverized soil—one, five or six inches deep, and the other fifteen or twenty inches deep—and place them in the sun at mid-day in summer. The thinner soil will be completely dried, while the deeper one, though it may have been dried in an oven at first, will soon accumulate a large amount of water on those particles which, being lower and more sheltered from the sun's heat than the particles of the thin soil, are made cooler.

With an open condition of subsoil, then, such as may be secured by under-draining, we fortify ourselves against drought.

2. Under-draining *admits an increased supply of atmospheric fertilizers*, because it secures a change of air in the soil. This change is produced when ever the soil becomes filled with water, and then dried; when the air above the earth is in rapid motion, and when the comparative temperature of the upper and lower soils changes. It causes new quantities of the ammonia and carbonic acid which it contains to be presented to the absorbent parts of the soil.

3. Under-draining *warms the lower parts of the soil*, because the deposit of moisture (1) is necessarily accompanied by an abstraction of heat from the atmospheric vapor, and because heat is withdrawn from the whole amount of air circulating through the cooler soil.

When rain falls on the parched surface soil, it robs it of a portion of its heat, which is carried down to equalize the temperature for the whole depth. The heat of the rain-water itself is given up to the soil, leaving the water from one to ten degrees cooler, when it passes out of the drains, than when received by the earth.

This heating of the lower soil of course renders it more favorable to vegetation.

4. Under-draining *hastens the decomposition of roots and other organic matters in the soil*, by admitting increased quantities of air, thus supplying *oxygen*, which is as essential in decay as it is in combustion. It also allows the resultant gases of decomposition to pass away, leaving the air around the decaying substances in a condition to continue the process.

This organic decay, besides its other benefits, produces an amount of heat perfectly perceptible to the smaller roots of plants, though not so to us.

5. Draining *accelerates the disintegration of the minerals in the soil*, by admitting water and oxygen to keep up the process. This disintegration is necessary to fertility, because the roots of plants can feed only on matters dissolved from *surfaces;* and the more finely we pulverize the soil, the more surface we expose. For instance, the interior of a stone can furnish no food for plants; while, if it were finely crushed, it might make a fertile soil.

Anything tending to open the soil to the air facilitates the disintegration of its particles, and thereby increases its fertility.

6. Draining *causes a more even distribution of nutritious matters among those parts of soil traversed by roots*, because it increases the ease with which water travels about, descending by its own weight, moving sideways by a desire to find its level or carried upward by attraction to supply the evaporation at the surface. By this continued motion of the water, soluble matter from one part of the soil may be carried to adjacent parts; and another constituent from this latter position may be carried back to the former. Thus the food of vegetables is evenly distributed through the soil. As soon as one particle is fully supplied with any element of plant nutrition, further amounts brought by water are carried to the next particle that can receive it—and so on, until the supply of soluble material is exhausted. This food is ready for absorption at any point where it is needed, while the more open character of the soil enables roots to occupy larger portions, making a more even drain on the whole, and preventing the undue impoverishment of any part.

7. Under-drains *improve the mechanical texture of the soil;* because, by the decomposition of its parts, as previously described (4 and 5), it is rendered of a character to be more easily worked; while smooth round particles, which have a tendency to pack, are roughened by the oxidation of their surfaces, and move less easily among each other.

8. By under-draining, *grasses are prevented from running out.* The grasses of meadows usually consist of *tillering* plants, which reproduce themselves

in sprouts from the upper parts of their roots, or from the joints of the roots. These sprouts become independent plants, and continue to tiller (thus keeping the land supplied with a full growth), until the roots of the *stools* (or clumps of tillers), come in contact with an uncongenial part of the soil, when the tillering ceases; the stools become extinct on the death of their plants, and the grasses run out.

The open and healthy condition of soil produced by draining prevents the tillering from being stopped so long as the fertility of the soil lasts, and thus keeps up a full growth of grass until the nutriment of the soil is exhausted.

9. Draining *enables us to deepen the surface-soil*, because the admission of air and the decay of roots, (which descend much deeper in drained than in undrained land,) render the condition of the sub-soil such, that it may be brought up and mixed with the surface-soil, without injuring its quality.

The second class of advantages of under-draining, arising in the removal of the excess of water in the soil, are quite as important as those just described.

10. *Soils are, thereby, rendered earlier in spring*, because the water, which rendered them cold, heavy, and untillable, is earlier removed, leaving them earlier in a growing condition.

11. *The throwing out of grain in winter* is lessened, because the water falling on the earth is immediately removed instead of remaining to throw up

the soil by freezing, as it always does, from the upright position taken by the particles of ice.

12. *We are enabled to work sooner after rains*, because the water descends, and is immediately removed, instead of lying to be taken off by the slow process of evaporation, and sinking through a heavy soil.

13. *The effects of cold weather are kept off longer in the fall*, by the removal of the excess of water which would produce an unfertile condition on the first appearance of cold weather.

The drains also, from causes already named (3), keep the soil warmer than before being drained, thus actually lengthening the season, by making the soil warm enough for vegetable growth earlier in spring, and later in autumn.

14. *Lands are prevented from becoming sour by the formation of acetic acid*, etc., because these acids are produced in the soil only when organic matter decomposes in contact with an excessive quantity of water. If the water is removed, the decomposition of the organic matter assumes a healthy form, while the acids already produced are neutralized by atmospheric influences, and the soil is restored to a condition in which it is fitted for the growth of the more valuable plants.

15. The *decay of roots*, etc., is allowed to proceed, because the preservative influence of too much water is removed. Wood, leaves, or other vegetable matter kept continually under water, will last for ages; while, if exposed to the action of the weather, as in under-drained soils, they soon decay.

The presence of too much water, by excluding the oxygen of the air, prevents the *comminution of mineral matters* necessary to fertility.

16. *The evaporation of water, and the consequent cooling of the soil, is in a great measure prevented* by draining the water out at the *bottom* of the soil, instead of leaving it to be dried off from the surface.

When water assumes the gaseous (or vapory) form, it occupies nearly 2000 times the space it occupied as a liquid, and as the vapor is of the same temperature as the liquid, it follows that it contains vastly more heat. A large part of this heat is derived from surrounding substances. When water is sprinkled on the floor, it cools the room; because, as it becomes a vapor, it takes heat from the room. The reason why vapor does not *feel* hotter than liquid water is, that, its heat is diffused through the larger mass, so that a cubic inch of vapor, into which we place the bulb of a thermometer, contains no more heat than a cubic inch of water. The principle is the same in some other cases. A sponge containing a tablespoonful of water is just as *wet* as one twice as large containing two spoonfuls.

If a wet cloth be placed on the head, and the evaporation of its water assisted by fanning, the head becomes cooler—a portion of its heat being taken to sustain the vapory condition of the water.

The same principle holds true with the soil. When the evaporation of water is rapidly going on, by the assistance of the sun, wind, etc., a large quantity of heat is abstracted, and the soil becomes cold.

This cooling of the soil by the evaporation of water, is of very great injury to its power of producing crops, and the fact that under-drains lessen it, is one of the best arguments in favor of their use. Some idea may, perhaps, be formed of the amount of heat taken from the soil in this way, from the fact that, in midsummer, twenty-five hogsheads of water may be evaporated from a single acre in twelve hours.

17. When not saturated with water the soil admits the water of rains, etc., which bring with them *fertilizing gases from the atmosphere*, to be deposited among the absorbent parts of the soil, and given up for the necessities of the plant. When this rain falls on lands already saturated, it cannot enter the soil, but must run off from the surface, or be removed by evaporation, either of which is injurious. The first, because fertilizing matter is washed away. The second, because the soil is deprived of necessary heat.

18. *The formation of crust on the surface of the soil* is due to the evaporation of the water of the soil. It arises partly from the fact that the water in the soil is saturated with mineral substances, which it leaves at its point of evaporation at the surface. This soluble matter often forms a very hard crust, which is a complete shield to prevent the admission of air with its ameliorating effects, and should, as far as possible, be avoided. Under-draining is the best

means of doing this, as it is the best means of lessening the evaporation, and of preventing the puddling of the clay in the soil.

The foregoing are some of the more important reasons why under-draining is always beneficial. Thorough experiments have amply proved the truth of the theory.

"Land which requires draining is that which, at some time during the year, (either from an accumulation of the rains which fall upon it, from the lateral flow or soakage from adjoining land, from springs which open within it, or from a combination of two or all of these sources,) becomes filled with water that does not readily find a natural outlet, but remains until removed by evaporation. Every considerable addition to its water wells up, and soaks its very surface; and that which is added after it is already brim-full, must flow off over the surface, or lie in puddles upon it. Evaporation is a slow process, and it becomes more and more slow as the level of the water recedes from the surface, and is sheltered by the overlying earth from the action of sun and wind. Therefore, at least during the periods of spring and fall preparation of the land, during the early growth of plants, and often even in midsummer, the *water-table*,—the top of the water of saturation,—is within a few inches of the surface, preventing the natural descent of roots, and, by reason of the small space to receive fresh rains, causing an interruption of work for some days after each storm.

"If such land is properly furnished with tile drains, (having a clear and sufficient outfall, offering sufficient means of entrance to the water which reaches them, and carrying it, by a uniform or increasing descent, to the outlet,) its water will be removed to nearly, or quite, the level of the floor of the drains, and its water-table will be at the distance of some feet from the surface, leaving the spaces between the particles of all the soil above it filled with air instead of water. The water below the drains stands at a level, like any other water that is dammed up. Rain-water falling upon the soil, will descend by its own weight to this level, and the water will rise into the drains, as it would flow over a dam, until the proper level is again obtained. Spring-water entering from below, and water oozing from the adjoining land, will be removed in like manner, and the usual condition of the soil, above the water-table, will be that which is best adapted to the growth of useful plants.

"In the heaviest storms, some water will flow over the surface of even the dryest beach sand; but in a well-drained soil the water of ordinary rains will be at once absorbed, will slowly descend toward the water- able, and will be removed by the drains so rapidly, even in heavy clays, as to leave the ground fit for cultivation, and in a condition for steady growth, within a short time after the rain ceases. It has been estimated that a drained soil has room between its particles for about one quarter of its bulk of water, that is, four inches of drained soil contains free space enough to receive a rain-fall one inch in depth, and, by the same token, four feet of drained soil can receive twelve inches of rain,—more than is known to have ever fallen in twenty-four hours since the deluge, and more than *one quarter of the annual rain-fall in the United States.*"*

Of the precise *profits* of under-draining this is not the place to speak: many of the agricultural papers contain numerous accounts of its success. It may be well to remark here, that many English farmers give it, as their experience, that under-drains on heavy clay lands in ordinary cultivation, pay for themselves every three years, or that they produce a perpetual profit of 33⅓ per cent., on their original cost. This is not the opinion of *theorists* and *book farmers*. It is the conviction of practical men, who know, *from experience*, that under-drains are beneficial.

The best evidence of the utility of under-draining is the position, with regard to it, which has been taken by the English national government, which affords much protection to the agricultural interests of the people,—a protection which in this country is unwisely and unjustly withheld.

In England, a very large sum from the public treasury has been appropriated as a fund for loans, on under-drains, which was lent to farmers for the purpose of under-draining their estates, the only security given being the increased value of the soil. The time allowed for payments was twenty years,

* Draining for Profit and Health, p. 22.

and only five per cent. interest is charged. By the influence of this patronage, the actual wealth of the kingdom has been rapidly increased, while the farmers themselves can raise their farms to the highest fertility, without immediate investment for draining.

The best proof that the government has not acted injudiciously in this matter is, that private capitalists employ their money in the same manner, and loans on under-drains are considered a very safe investment.

One very important, though not strictly agricultural, effect of thorough drainage is its removal of certain local diseases, peculiar to the vicinity of marshy or low moist soils. The health-reports in several places in England, show that where *fever and ague* was once common, it has almost entirely disappeared since the general use of under-drains in those localities.

CHAPTER IV.

SUB-SOIL PLOWING.

The *sub-soil plow* is an implement differing in figure from the surface plow. It does not turn a furrow, but merely runs through the sub-soil like a mole—loosening and making it finer by lifting, but allowing it to fall back and occupy its former place. It usually follows the surface plow, entering the soil to the depth of from eight to fifteen inches below the bottom of the surface furrow.

The best pattern now made (the steel sub-soil plow) is represented in the following figure.

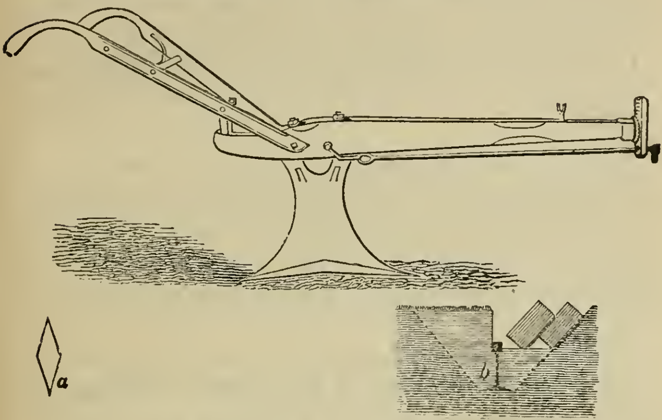

FIG. 6.—Wrought Iron and Steel Sub-soil Plow.

The sub-soil plows first made raised the whole soil about eight inches, and required very great power in their use, often six or eight oxen. The implement shown in the figure, raising the soil but slightly, may be worked with much less power, and produces equally good results. It may be run to a good depth in most soils by a single yoke of oxen.

The motion of any part of the soil which is effected by this sub-soil plow is very slight, but it is exerted throughout the whole mass of the soil above the plow and for a considerable distance sideways toward the surface. If the land is too wet, this motion will be injurious rather than beneficial, but if it is dry enough to crumble, it will be very much loosened. If we hold in the hand a ball of dry clay, and press it hard enough to produce the least motion among its particles, the whole mass becomes pulverized. On the same principle, the sub-soil plow renders the compact lower soil sufficiently fine for the entrance of roots.

Notwithstanding its great benefits on land, which is sufficiently dry, sub-soiling cannot be recommended for wet lands; for, in such case, the rains of a single season would often be sufficient to entirely overcome its effects by packing the sub-soil down to its former hardness.

On lands not overcharged with water, it is productive of the best results, it being often sufficient to turn the balance between a gaining and a losing business in farming.

It increases nearly every effect of under-draining; especially does it overcome drought, by loosening the soil, and admitting air to circulate among the particles of the sub-soil, and deposit its moisture, on the principle described in the chapter on under-draining.

It deepens the surface-soil, because it admits roots into the sub-soil where they decay and leave carbon, while the circulation of air so affects the mineral parts, that they become of a fertile character. As a majority of roots decay in the surface soil, they there deposit much mineral matter obtained from the sub-soil, and thus render it richer.

The retention of atmospheric manures is more fully insured by the better exposure of the clayey portions of the soil.

The sub-soil often contains matters which are deficient in the surface-soil. By the use of the sub-soil plow, they are rendered available.

Sub-soiling is similar to under-draining in continuing the tillering of grasses.

When the sub-soil is a thin layer of clay on a sandy bed (as in many parts of the country), the sub-soil plow, by passing through it, opens a passage for water, and often affords a sufficient drainage.

If plants will grow better on a soil six inches deep than on one of three inches, there is no reason why they should not be benefited in proportion, by disturbing the soil to the whole depth to which roots will travel—even to a depth of two feet. The minute rootlets of corn and most other plants will, if allowed by cultivation, occupy the soil to a greater depth than this, having a fibre in nearly every cubic inch of the soil for the whole distance. There are very few cultivated plants whose roots would not travel to a depth of thirty inches or more. Even the onion sends its roots to the depth of eighteen inches when the soil is well cultivated.

The object of loosening the soil is to admit roots to a sufficient depth to hold the plant in its position, —to obtain the nutriment necessary to its growth,— to receive moisture from the lower portions of the soil,—and, if it be a bulb, tuber, or tap, to assume the form requisite for its largest development.

It must be evident that roots, penetrating the soil to a depth of two feet, anchor the plant with greater stability than those which are spread more thinly near the surface.

The roots of plants traversing the soil to such great distances, and being located in nearly every part, absorb mineral and other food in solution in water, only through the *spongioles at their ends.* Consequently, by having these ends in *every part* of the soil, it is *all* brought under contribution, and the amount supplied is greater, while the demand on any particular part may be less than when the whole requirements of plants have to be supplied from a depth of a few inches.

The ability of roots to assume a natural shape in the soil, and grow to their largest size, must depend on the condition of the soil. If it is finely pulverized to the whole depth to which they ought to go, they will be fully developed; while, if the soil be too hard for penetration, they will be deformed or small. Thus a parsnip may grow to the length of two and a half feet, and be of perfect shape, while, if it meet in its course, at a depth of eight or ten inches, a *cold, hard* sub-soil, its growth must be arrested, or its form injured.

Roots are turned aside by a hard or wet sub-soil, as they would be if received by the surface of a plate of glass.

Add to this the fact that cold, impenetrable subsoils are *chemically* uncongenial to vegetation, and we have sufficient evidence of the importance, and in many cases the absolute necessity of sub-soiling and under-draining.

It is unnecessary to urge the fact that a garden soil of two feet is more productive than a field soil of six inches; and it is certain that proper attention to these two modes of cultivation will in a majority of cases make a garden of the field—more than doubling its value in ease of working, increased produce, certain security against drought, and more even distribution of the demands on the soil—while the outlay will be largely repaid by an immediate increase of crops.

The sub-soil will be much improved in its character the first year, and a continual advancement renders it in time equal to the original surface-soil, and extending to a depth of two feet or more.

The sub-soil plow has come into very general use. The implement has ceased to be a curiosity; and the man who now objects to its use, may be classed with him who shells his corn on a shovel over a half-bushel, instead of employing an improved machine, which will enable him to do more in a day than he can do in the "good old way" in a week.

In no case will the use of the sub-soil plow be found anything but satisfactory, except in occasional instances where there is some chemical difficulty in the sub-soil, which will be overcome by a year or two of exposure—and even such cases are extremely rare.

As was before stated, its use on wet lands is not advisable until they have been under-drained, as excess of water prevents its effects from being permanent.

CHAPTER V.

PLOWING AND OTHER PROCESSES FOR PULVERIZING THE SOIL.

The advantages of pulverizing the soil, and the *reasons* why it is necessary, have been sufficiently explained to need no further remark. Few farmers, when they plow, dig, or harrow, are enabled to give substantial reasons for the operation. If they will reflect on what has been said in the preceding chapters, concerning the supply of mineral food to the plant by the soil, and the effect of air and moisture about the roots, they will find more satisfaction in their labor.

PLOWING.

The kind of plow used in cultivating the surface-soil, must be decided by the kind of soil. This question the practical, *observing* farmer will be able to solve.

As a general rule, it may be stated that the plow which runs the *deepest*, with the same amount of force, is the best, but this rule is not without its exceptions.

The advantages of *deep plowing* cannot be too strongly urged.

The statement that the *deeper* and the *finer* the soil is rendered, the more productive it will become, is in every respect true, and no single instance will contradict it.

It must not be inferred from this, that we would advise a farmer, who has always plowed his soil to the depth of only six inches, to double the depth at once. Such a practice in some soils would be highly injurious, as it would completely bury the more fertile and better cultivated soil, and bring to the top one which contains no organic matter, and has never been subject to atmospheric influences. This would, perhaps, be so little fitted for vegetation that it would scarcely sustain plants until their roots could reach the more fertile parts below. Such treatment of the soil (turning it upside down) is excellent in *garden* culture, where the great amount of manures applied is sufficient to overcome the temporary barrenness of the soil, but it is not to be recommended for all *field* cultivation, where much less manure is employed.

The course to be pursued in such cases is to *plow a little deeper each year.* By this means the soil may be gradually deepened to any desired extent. The amount of uncongenial soil which will thus be brought up, is slight, and will not interfere at all with the fertility of the soil, while the elevated por tion will become, in a single year, so altered by exposure, that it will equal the rest of the soil in fertility.

Often where lime has been used in excess, it has sunk to the sub-soil, where it remains inactive. A slight deepening of the surface plowing would mix this lime with the surface-soil, and render it again useful.

When the soil is light and sandy, resting on a heavy clay sub-soil, or clay on sand, the bringing up of the mass from below will improve the texture of the upper parts.

As an instance of the success of deep plowing, we call to mind the case of a farmer in New Jersey, who had a field which had yielded about twenty-five bushels of corn per acre. It had been cultivated at ordinary depths. After laying it out in eight-step lands (24 feet,) he plowed it at all depths from five to ten inches on the different lands, and sowed oats evenly over the whole field. The crop on the five inch soil was very poor, on the six inch rather better, on the seven inch better still, and on the ten inch soil it was as fine as ever grew in New Jersey; it had stiff straw and broad leaves, while the grain was also much better than on the remainder of the field.

There is an old anecdote of a man who died, leaving his sons with the information that he had buried a pot of gold for them, somewhere on the farm. They commenced digging for the gold, and dug over the whole farm to a great depth without finding the gold. The digging, however, so enriched the soil that they were fully compensated for their disappointment, and became wealthy from the increased produce of their farm.

Farmers will find, on experiment, that they have gold buried in their soil, if they will but dig deep enough to obtain it. The law gives a man the ownership of the soil for an indefinite distance from the surface, but few seem to realize that there is *another farm* below the one they are cultivating, which is quite as valuable as the one on the surface, if it were but properly worked.

Fall plowing, especially for heavy lands, is the best means of securing the action of the frosts of winter to pulverize the soil. If it be a stiff clay, it will be well to throw the up-soil in high ridges (by ridging and back-furrowing,) so as to expose the largest possible amount of surface to the freezing and thawing of winter. This, with the rotting of the sod, (which is thus made ready for the feeding of plants,) makes the effects of fall plowing almost universally beneficial. The earlier the plowing is done, the more thoroughly the sod is rotted and prepared for the nutrition of the crop of the next year.

The great improvement of the age in the mechanical branch of agriculture, has been made in England, during the past ten or twelve years, in the application of the steam-engine to the work of cultivating the soil. It would be beyond the scope of a simple elementary book like this to enter fully into a description of the machinery by which this work is done, and the method of its operation ; but it is worthy of remark, that there are now in use in England about 500 sets of the apparatus, and that the system has been in successful operation there for about a dozen years. A single engine (of 14 horse power) moves to the field on its own wheels, carrying the tackle with it, and plows an acre an hour with ease, or draws a deep cultivator through from three to five acres in an hour. The engine stands on one headland, and a pulley-wheel on the other, an endless steel wire rope passes around a windlass under the engine, and around the pulley opposite. The gang of plows, or the wide cultivator, is drawn back and forth between the two.

THE HARROW AND CULTIVATOR.

The *harrow*, an implement largely used in all parts of the world, to pulverize the soil, and break clods, has become so firmly rooted in the affections of farmers, that it must be a very long time before they can be convinced that it is not the best implement for the use to which it is devoted. It is true that it pulverizes the soil for a depth of two or three inches, and thus much improves its appearance, benefiting it, without doubt, for the earliest stages of the growth of plants. Its action, however, is very defective, because, from the *wedge* shape of its teeth, it continually acts to *pack* the soil ; thus—although favorable for the germination of the seed—it is not calculated to benefit the plant during the later stages of its growth, when the roots require the soil to be pulverized to a considerable depth.

The *cultivator* may be considered an *improved harrow*, the principal difference between them being, that while the teeth of the harrow are pointed at the lower end, those of the cultivator are shaped like a small double plow, being large at the bottom and growing smaller toward the top. They lift the earth up, instead of pressing it downward, thus loosening instead of compacting the soil.

Many styles of cultivators are now sold at agricultural warehouses. A very good one, for field use, may be made by substituting the cultivator teeth for the spikes in an old harrow frame.

CHAPTER VI.

ROLLING, MULCHING, WEEDING, ETC.

ROLLING.

Rolling the soil with a large roller, drawn by a team, is in many instances a good accessory to cultivation. By its means, the following results are obtained :—

1. The soil at the surface is pulverized without the compacting of the lower parts, the area of contact being large.

2. The stones on the land are pressed down so as to be out of the way of the mowing machine.

3. The soil is compacted around seeds after sowing in such a manner as to exclude light and to *touch* them in every part, both of which are of essential advantage in their germination, and assist in giving them a good start.

4. When the soil is smoothed in this manner, there is less surface exposed for the evaporation of water with its cooling effect.

5. Light sandy lands, by being rolled in the fall are rendered more compact, and the loosening effects of frequent freezing and thawing are lessened.

6. The most important use of the roller is in compacting the earth about the roots of grass and grain crops early in the spring. The freezing and thawing of winter leave them usually partly uncovered, or surrounded by air spaces. Their best growth requires that these roots be closely pressed by the earth, —and this pressure is given by the roller better than in any other way.

If well under-drained, a large majority of soils would doubtless be benefited by a judicious use of the roller.*

MULCHING.

Mulching consists in covering the soil with salt hay, litter, seaweed, leaves, spent tanbark, chips, or other refuse matter.

Every farmer must have noticed that, if a board or

* Field rollers should be made in sections, for ease of turning

rail, or an old brush-heap, be removed in spring from soil where grass is growing, the grass afterward grows in those places much larger and better than in other parts of the field.

This improvement arises from various causes.

1. The evaporation of water from the soil is prevented during drought by the shade afforded by the mulch; and it is therefore kept in better condition, as to moisture and temperature, than when evaporation goes on more freely. This condition is well calculated to advance the chemical changes necessary to prepare the matters—both organic and mineral—in the soil for the use of plants.

2. A heavy mulch breaks the force of rains, and prevents them from compacting the soil, as would be the result were no such precaution taken.

3. Mulching protects the surface-soil from freezing as readily as when exposed, and thus keeps it longer open for the admission of air and moisture. When unprotected, the soil early becomes frozen; and all water falling, instead of entering, as it should do, passes off over the surface.

5. The throwing out of winter grain is often prevented, because this is due to the frequent freezing and thawing of the surface-soil.

6. When the wet surface-soil freezes, it is raised up, and the young plants growing in it are raised with it; when the frost is thawed out, the soil falls back to its original position, while parts of the crowns or roots of the crop remain raised. The next freeze takes hold of them lower down, and lifts them again;

the next thaw leaves them higher than ever,—until in spring, sometimes, the crown of a shoot of wheat will be standing several inches above the level of the soil. The use of a mulch prevents both the freezing and the thawing from being so frequent and active as they would be if no protection were used.

7. It also prevents the "baking" of the soil, or the formation of a crust.

Nursery-men often keep the soil about the roots of young trees mulched continually. One of the chief arguments for this treatment is, that it prevents the removal of the moisture from the soil and the consequent loss of heat. Also that it keeps up a full supply of water for the uses of the roots, because it keeps the surface of the soil cool, and causes a deposit of dew.

It has been suggested, and is undoubtedly true, that a mulch on the ground, by affording a good shelter for minute (microscopic) insects, causes them to accumulate in such quantities as to add (by their eggs, their excrement, and their dead bodies) to the fertilizing matter in the soil. How important this addition may be, we cannot of course know, but it is certain that mulching exercises greater good effect than can reasonably be attributed, in the present state of our knowledge, to any or all of the above described actions.

It is the opinion of many, that at least one-half of the beneficial effect of seaweed, or coarse stable manure, when used as a top dressing, is due to its action as a mulch.

It is a good plan to sow oats very thinly over land intended for winter fallow, after the removal of crops, as they will grow a little before being killed by the frost, when they will fall down, thus affording a very beneficial mulch to the soil.

When farmers spread coarse manure on their fields in the fall to be plowed under in the spring, they benefit the land by the mulching, perhaps as much as by the addition of fertilizing matter, because they give it the protecting influence of the straw, etc.

It is an old and true saying that "snow is the poor man's manure." One reason why it is so beneficial is, that it acts as a most excellent mulch. It contains no more ammonia than rain-water does; and, were it not for the fact that it protects the soil against loss of heat, and produces other benefits of mulching, it would have no more advantageous effect. The severity of the winters at the North is largely compensated for by the long duration of snow.

It is well known that when there is but little snow in cold countries, wheat is very liable to be *winter killed*. An evenly spread mulch, and thorough draining, will greatly prevent this.

This treatment is peculiarly applicable to the cultivation of flowers, both in pots and in beds out of doors. It is almost indispensable to the profitable production of strawberries, and many other garden crops, such as asparagus, rhubarb, etc. An excellent treatment for newly transplanted trees, is to put stones about their roots. A good *mulching*, by the use of leaves, copying the action of nature in forests, has nearly as good an effect; for it is chiefly as a mulch that the stones are beneficial.

WEEDING.

If a farmer were asked—what is the use of weeds? he might make out quite a list of their benefits, among which might be some of the following:—

1. They shade tender plants, and in a measure serve as a mulch to the ground.

2. Some weeds, by their offensive odor, drive away many insects.

3. They may serve as a green crop to be plowed into the soil, and increase its organic matter.

4. *They make us stir the soil*, and thus increase its fertility.

Still, while thinking out these excuses for weeds (all but the last of which are very feeble ones), he would see other and more urgent reasons why they should not be allowed to grow.

1. They occupy the soil to the disadvantage of crops.

2. They exclude light and heat from cultivated plants, and thus interfere with their growth.

3. They take up mineral and other matters from the soil, and hold them during the growing season, thus depriving crops of their use.

It is not necessary to argue the injury done by weeds. Every farmer is well convinced that they should be destroyed, and the best means of accomplishing this is of the greatest importance.

In the first place, we should protect ourselves against their increase. This may be done (in a measure):—

By decomposing all manures in compost, whereby many of the seeds contained will be killed by the heat of fermentation.

By hoeing, or otherwise destroying growing weeds before they mature their seeds; and

By keeping the soil in the best chemical condition.

This last point is one of much importance. It is well known that soils deficient in potash will naturally produce one kind of plants, while soils deficient in phosphoric acid will produce plants of another species, etc. Many soils produce certain weeds which would not grow on them spontaneously if they were fitted for the growth of better plants. It is also believed that those weeds, which naturally grow on the most fertile soils, are the ones most easily destroyed. There are exceptions (of which the Thistle is one), but this is given as a general rule.

By careful attention to the foregoing points, weeds may be kept from increasing, while those already in the soil may be eradicated in various ways, chiefly by mechanical means, such as hoeing, plowing, etc.

Prof. Mapes used to say, and experience often shows, that six bushels of salt annually sown broadcast over each acre of land, will destroy very many weeds, as well as grubs and worms.

The *common hoe* is a very imperfect tool for the purpose of removing weeds, as it prepares a better soil for, and replants in a position to grow, nearly as many weeds as it destroys.

The *scuffle-hoe* (or push-hoe) is much more effective, as, when worked by a man walking backward, and retiring as he works, it leaves nearly all of the weeds on the surface of the soil to be killed by the sun. When used in this way, the earth is not trodden on after being hoed—as is the case when the common hoe is employed. This treading, besides compacting the soil, covers the roots of many weeds, and causes them to grow again.

The scuffle-hoe, however, except in very light soil, will not run so deeply as it is often desirable to loosen it, and must, in such cases, be superseded by the *prong-hoe* (or potato-hook), which is a capital substitute for the common hoe in nearly all cases.

Much of the labor of weeding usually performed by men, might be more cheaply done by horses. There are various implements for this purpose, some of which have come into very general use.

One of the best of these is the *Langdon Horse Hoe*, which is a shovel-shaped plow, to be run one or two inches deep. It has a wing on each side to prevent the earth from falling on to the plants in the rows. At the rear, or upper edge, is a kind of rake or comb, which allows the earth to pass through, while the weeds pass over the comb and fall on the surface of the soil, to be killed by the heat of the sun. It is a simple and cheap tool, and will perform the work of twenty men with hoes. The hand hoe will be necessary only in the rows.

CULTIVATORS.

The *cultivator*, which was described in the preceding chapter, and of which there are various patterns in use, is excellent for weeding and for loosening the soil between the rows of corn, etc. The one called the *universal* cultivator, having its side bars made of iron, curved so that at whatever distance it is placed the teeth will point *straight forward*, is a much better tool than those of the older patterns, which had the teeth so arranged that when set for wide rows, they pointed toward the clevis. It is difficult to keep such a cultivator in its place, while the "*universal*" is as difficult to move out of a straight line.

IMPROVED HORSE-HOE.

The *improved* (or Knox's) *horse-hoe*, is a combina-

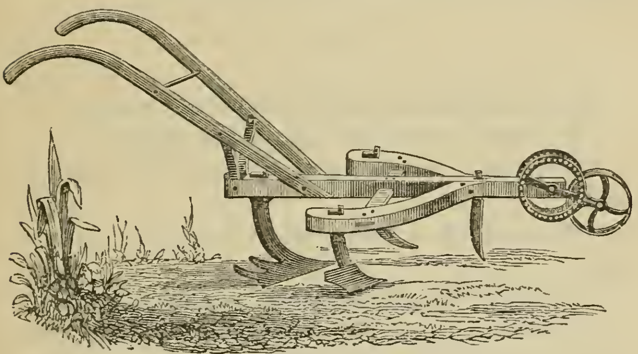

FIG. 7.

tion of the "Langdon" horse-hoe and the cultivator, and is the best implement, for many purposes, that has yet been made.

An excellent tool, called a Muller, is used in Rhode

Island. It consists of a stick of heavy wood, five or six feet long and about three inches by six inches in size, drawn by fastening one trace to each end, having stilts or handles rising from the upper side, and two rows of sharpened iron teeth six inches long on the under side—the front row of teeth point forward, and the rear row backward. It is a "horse-rake" for the ground, and leaves it as fine as a hand-rake would, while it works it much more deeply.

One of the best cultivators that it is possible to use between rows of corn—or other plants—is a small sub-soil plow of the kind shown on p. 201, drawn by one horse, and running five or six inches deep. It mellows the land deeply and thoroughly.

There is much truth in the following proverbs:

"A garden that is well kept, is kept easily."

"You must conquer weeds, or weeds will conquer you."

"The best time to kill weeds is before they come up."

It is almost impossible to give a *recapitulation* of the matters treated in this section, as it is, itself, but an outline of subjects which might occupy our whole book. The scholar and the farmer should understand every principle which it contains as well as they understand the multiplication table; and their application will be found, in every instance, to produce the best results.

The two great rules of mechanical cultivation are—

THOROUGH UNDER-DRAINING.

DEEP AND FREQUENT DISTURBANCE OF THE SOIL.

SECTION FIFTH.

ANALYSIS.

SECTION FIFTH.

ANALYSIS.

CHAPTER I.

At the time when this book was first written, in 1853, it was the very general opinion of scientific, and of many practical, men, that it was within the power of the chemist, by separating the different parts of the soil, weighing each, to determine whether the soil were fertile or barren; how long it might continue fertile without the use of manure; what manures were best suited to restoring or preserving its fertility; and what class of plants it was best fitted to produce.

In this belief, these pages were devoted, very largely, to showing the farmer how he could best regulate his operations in the light of such teachings as soil analysis gives.

As is often the case in the adoption of new discoveries, a further acquaintance with the subject showed that, so far as the processes of practical agriculture are concerned, soil analysis is of but little, if any, value. True, the amount of potash, for instance, which is contained in the soil, may be determined with great precision, and it seemed, at first, that this sort of knowledge was enough for practical use; but further research and reasoning have shown that the question of *quantity* is of no more consequence than the question of *condition*. Of the potash in the soil only the $\frac{1}{100}$ or the $\frac{1}{1000}$ part is available to the plants of a single year's growth;—why the other 99, or 999 parts are not available, and how they may be made so, the soil analysis, from which so much was hoped for, does not tell us.

The causes of fertility and barrenness lie beyond the reach of weight and measure, and it is an unfortunate truth that, aside from a very simple indication of the internal character of our soils, the science of chemistry can only help us in studying their character when we follow it through the by-ways of its more subtle reasoning. Much of what is known of the manner in which the soil gives nutriment to the plant has been learned from the bringing together of the results of many experiments,—studying them by the light of what chemistry has positively taught. This knowledge is of great value, and is sufficient to form the foundation of a really scientific agriculture; but there is no doubt that much more is yet to be learned, and that we are still very far from knowing all that we must know of the use of manures, the functions of the soil, and the growth of plants.

While waiting for its further instruction, let us make the best possible use of what chemistry now teaches with certainty, in the analysis of the ashes of plants, and of manures.

Practice and science have combined to show us how all soils may be raised to a high, possibly to the highest, state of fertility, and a knowledge of the composition of crops and manures shows how we may best maintain its good condition.

The one safe rule for all farmers to adopt is the following:—

ALWAYS RETURN IN THE EARTHY CONSTITUENTS OF MANURE THE FULL EQUIVALENT OF THE EARTHY CONSTITUENTS OF THE CROP.

This will prevent the soil from deteriorating, and we may safely trust to the process of cultivation, and to the action of atmospheric influences, to make it yearly better, by developing fresh supplies of its ash-forming parts.

CHAPTER II.

TABLES OF ANALYSIS.

ANALYSES OF THE ASHES OF CROPS.

No. I.

	Wheat.	Wheat Straw.	Rye.	Rye Straw.
Ashes in 1000 dry parts......	20	60	24	40
Silica (*sand*)................	16	654	5	645
Lime..........................	28	67	50	91
Magnesia..........	120	33	104	24
Peroxide of Iron.............	7	13	14	14
Potash.....................	237	124	221	174
Soda.........................	91	2	116	3
Chlorine...................		11		5
Sulphuric Acid..............	3	58	10	8
Phosphoric Acid.............	498	31	496	38

No. II.

	Corn.	Corn Stalks.	Barley.	Barley Straw.
Ashes in 1000 dry parts......	15	44	28	61
Silica (*sand*)................	15	270	271	706
Lime........................	15	86	26	95
Magnesia	162	66	75	32
Peroxide of Iron.............	3	8	15	7
Oxide of Manganese..........				1
Potash.....................	261	96	136	62
Soda.......................	63	277	81	6
Chlorine....................	2	20	1	10
Sulphuric Acid..............	23	5	1	16
Phosphoric Acid.............	449	171	389	31

No. III.

	Oats.	Oat Straw.	Buck Wheat.	Potatoes.
Ashes in 1000 dry parts........	20	51	21	90
Silica (*sand*)..................	7	484	7	42
Lime........................	60	81	67	21
Magnesia.....................	99	38	104	53
Peroxide of Iron..............	4	18	11	5
Potash.......................	262	191	87	557
Soda.........................		97	201	19
Chlorine.....................	3	32		43
Sulphuric Acid................	104	33	22	137
Phosphoric Acid..............	438	27	500	126
Organic Matter...............				750 Water.

No. IV.

	Peas.	Beans.	Turnips.	Turnip Tops.
Ashes in 1000 dry parts........	25	27	76	170
Silica (*sand*)..................	5	12	71	8
Lime........................	53	58	128	233
Magnesia.....................	85	80	48	31
Peroxide of Iron..............	10	6	9	8
Potash.......................	361	336	398	286
Soda.........................	91	106	108	54
Chlorine.....................	23	7	37	160
Sulphuric Acid................	44	10	131	125
Phosphoric Acid..............	333	378	67	93
Organic Matter...............			870 Water.	

No. V.

	Flax.	Linseed.	Meadow Hay.	Red Clover.
Ashes in 1000 dry parts......	50	46	60	75
Silica (*sand*)..................	257	75	344	48
Alumina (*clay*)...............	37?			
Lime.........................	148	83	196	371
Magnesia....................	44	146	78	46
Peroxide of Iron..............	36?	9	7	2
Potash........................	117	240	236	267
Soda.........................	118	45	19	71
Chlorine.....................	29	2	28	48
Sulphuric Acid................	32	23	29	60
Phosphoric Acid..............	130	365	58	88

No. VI.

Amount of Inorganic Matter removed from the soil by ten bushels of grains, etc., and by the straw, etc., required in their production—estimated in pounds:

	Wheat.	1200 lbs. Wheat Straw.	Rye.	1620 lbs. Rye Straw.
Potash........................	2.86	8.97	2.51	11.34
Soda.........................	1.04	.12	1.33	.20
Lime.........................	.34	4.84	.56	5.91
Magnesia....................	1.46	2.76	1.18	1.58
Oxide of Iron................	.08	.94	.15	.88
Sulphuric Acid...............	.03	4.20	.11	.05
Phosphoric Acid..............	6.01	2.22	5.64	2.49
Chlorine.....................		.79		.30
Silica........................	.14	47.16	.05	42.25
Pounds carried off............	12	72	11½	66

No. VII.

	Corn	1620 lbs. Corn Stalks.	Oats.	700 lbs. Oat Straw.
Potash	2 78	6.84	1.69	12.08
Soda		19.83		
Lime	.12	6.02	.39	3.39
Magnesia	1.52	4.74	.64	1.59
Oxide of Iron		.57	.02	.78
Sulphuric Acid		.36	.66	1.41
Phosphoric Acid	4.52	12.15	2.80	1.07
Chlorine		1.33	.02	1.36
Silica	.06	19.16	.18	20.32
Pounds carried off	9	71	6½	42

No. VIII.

	Buck Wheat.	Barley.	660 bbls. Barley Straw.	2000 lbs. Flax.
Potash	1.01	1.90	2.57	11.78
Soda	2.13	1.18	.23	11.82
Lime	.78	.96	3.88	11.85
Magnesia	1.20	1.00	1.31	9.38
Oxide of Iron	.14	.20	-.90	7.32
Sulphuric Acid	.25	.01	.66	3.19
Phosphoric Acid	5.40	5.35	1.25	13.05
Chlorine		.01	.40	2.90
Silica	.09	3.90	28.80	25.71
Pounds carried off	11	14	40	100

No. IX.

	Beans.	1120 lbs. Bean Straw.	Field Peas.	1366 lbs. Pea Straw.
Potash	5.54	36.28	5.90	3 78
Soda	1.83	1.09	1.40	
Lime	98.98	13.60	.81	43.93
Magnesia	.28	4.55	1.30	5.50
Oxide of Iron	.10	.20	.15	1.40
Sulphuric Acid	.16	.64	.64	5.43
Phosphoric Acid	7.80	5.00	5.50	3.86
Chlorine	.13	1.74	.23	.08
Silica	.18	4.90	.7	16.02
Pounds carried off	17	68	16	80

No. X.

	1 Ton Turnips.	635 lbs. Turnip Tops.	1 Ton Potatoes.	2000 lbs. Red Clover.
Potash	7.14	4.34	27.82	31.41
Soda	.86	.84	.93	8.34
Lime	2.31	3.61	1.03	43.77
Magnesia	.91	.48	2.63	5.25
Oxide of Iron	.23	.13	.26	.23
Sulphuric Acid	2.30	1.81	6.81	7.05
Phosphoric Acid	1.29	1.31	6 25	10.28
Chlorine	.61	2.35	2.13	5.86
Silica	1.36	.13	2.14	5.81
Pounds carried off	17	15	50	118

No. XI.

	2000 lbs. Meadow Hay.	2000 lbs. Cabbage. Water 9–10
Potash	18.11	5.25
Soda	1.35	9.20
Lime	22.95	9.45
Magnesia	6.75	2.70
Oxide of Iron	1.69	.25
Sulphuric Acid	2.70	9.60
Phosphoric Acid	5.97	5.60
Chlorine	2.59	2.60
Silica	37.89	.35
Pounds carried off	100	45

No. XII.

Composition of Ashes, leached and unleached, showing their manurial value:

	Oak unleached.	Oak leached.	Beech unleached.	Beech leached.
Potash	84		158	
Soda	56		29	
Lime	750	548	634	426
Magnesia	45	6	113	70
Oxide of Iron	6		8	15
Sulphuric Acid	12		14	
Phosphoric Acid	35	8	31	57
Chlorine			2	

No. XIII.

	Birch leached.	Seaweed unleached.	Bituminous Coal unleached.
Potash		180	2
Soda		210	2
Lime	522	94	21
Magnesia	30	99	2
Oxide of Iron	5	3	40
Sulphuric Acid		248	9
Phosphoric Acid	43	52	2
Chlorine		98	1

No. XIV.

TOBACCO.

Analysis of the ash of the PLANT [Will & Fresenius]—

Potash	19.55
Soda	0.27
Magnesia	11.07
Lime	48.68
Phosphoric Acid	3.66
Sulphuric Acid	3.29
Oxide of Iron	2.99
Chloride of Sodium	3.54
Loss	6.95
	100.00

Analysis of the ash of the ROOT [Berthier]—

Soluble Matter	12.3
Insoluble Matter	87.7
The Soluble parts consist of nearly—	
Carbonic Acid	10.0
Sulphuric Acid	10.3
Muriatic Acid (Chlorine, &c.)	18.26
Potash and Soda	61.44
	100 00

No. XV.

Composition of some of the more common Compounds of Acids and Alkalies.

100 Parts of	Contain of the Alkalies.		Contain of the Acids.	
Carbonate of Potash (Pearlash)	Potash	68·09	Carbonic	31·91
Bi-Carbonate of Potash (Saleratus)	do.	51·62	Carbonic	48·38
Nitrate of Potash (Saltpetre)	do.	46 56	Nitric	53·44
Silicate of Potash	do.	50·54	Silicic	49·46
Carbonate of Soda	Soda	58·58	Carbonic	41·42
Bi-Carbonate of Soda (Common Soda)*	do.	41·42	Carbonic	58·58
Nitrate of Soda	do.	36·60	Nitric	63·40
Sulphate of Soda (Glauber Salts)*	do.	19·38	Sulphuric	24·85
Silicate of Soda	do.	40·37	Silicic	59·63
Carbonate of Lime (Limestone)	Lime	56·29	Carbonic	43·71
Sulphate of Lime (Plaster Paris)*	do.	32·90	Sulphuric	46·31
Sulphate of Lime (Burned)	do.	41·53	Sulphuric	58·47
Phosphate of Lime	do.	54·48	Phosphoric	45·52
Super-Phosphate of Lime	do.	28.52	Phosphoric	71·48
Silicate of Lime	do.	38·15	Silicic	61·85
Carbonate of Magnesia	Magnesia	48·31	Carbonic	51·69
Sulphate of Magnesia (Epsom Salts)*	do.	16·70	Sulphuric	32·40
Silicate of Alumina	Alumina	27·05	Silicic	72·95
Sulphate of Iron (Green Vitriol)*	Oxide of Iron	27·19	Sulphuric	31·03

* Contain a large amount of Water.

No. XVI.

Proximate Analyses of Crops, showing the amount of the different Organic Compounds contained in Grain, Roots, Hay, etc.—estimated in pounds :

		Water.	Husk or Woody Fibre.	Starch, Gum and Sugar.	Gluten, Albumen, Legumin.	Fatty Matter.
10 Bushels.						
Wheat	600 lbs.	90	90	330	87	18
Barley	515 lbs.	77	77	309	70	13
Oats	425 lbs.	68	85	255	70	25
Rye	520 lbs.	62	78	312	65	18
Indian Corn	600 lbs.	84	36	420	72	42
Buck Wheat	425 lbs.	64	106	212	34	27
Beans	640 lbs.	90	61	256	166	16
Peas	640 lbs.	90	58	320	154	14
2000 lbs.						
Potatoes		1500	80	360	40	6
Turnips		1760	40	180*	30	6
Carrots		1700	60	200*	30	5
Mangold Wurtzel		1700	40	220*	40	7
Meadow Hay		280	600	800	140	70
Clover Hay		280	500	800	186	80
Pea Straw		250	500	900	246	30
Rye Straw		270	900	760	26	7
Corn Stalks		240	500	1040	60	34
100 lbs. Fine Wheat Flour		10		79	11	
100 lbs. Wheat Bran		13		55	19	5

* Pectic Acid.

No. XVII.

Amount of Ash left after burning 1000 lbs. of varicns plants, ordinarily dry·

Wheat	20		its straw	50
Barley	30		"	50
Oats	40		"	60
Rye	20		"	40
Indian Corn	15		"	50
Pea	30		"	50
Bean	30			
Meadow Hay	50	to 100		
Clover "	90			
Rye Grass "	95			
Potato	8	to 15		
Turnip	5	to 8		
Carrot	15	to 20		

No. XVIII.

MANURES.

HORSE MANURE.

Solid Dung—

Combustible Matter	19.68
Ash	3.07
Water	77.25
	10.000

Composition of the Ash—

Silica	62.40
Potash	11.30
Soda	1.98
Oxide of Iron	1.17
Lime	4 63
Magnesia	3.84
Oxide of Manganese	2.13
Phosphoric Acid	10.49
Sulphuric Acid	1.89
Chlorine	0.05
Loss	0.14
	100.00

No. XIX.

NIGHT SOIL.

Solid (Ash) –			
	Earthy Phosphates, and a trace of Sulphate of Lime		106
	Sulphate of Soda and Potash, and Phosphate of Soda		8
	Carbonate of Soda		8
	Silica		16
	Charcoal and Loss		18
			150
Urine—			
	Urea*	30.10	
	Uric Acid	1.00	
	Sal Ammoniac*	1.50	
	Lactic Acid, etc	17.14	
	Mucus	.32	
	Sulphate of Potash	3.71	
	Sulphate of Soda	3.16	
	Phosphate of Ammonia*	1.65	
	Earthy Phosphates	3.94	
	Salt (Chloride of Sodium)	4.45	
	Silica	0.03	
			67.00
Water			933.00
			1000.00

* Supply Ammonia.

No. XX.

COW MANURE.

Solid (Ash)—		
	Phosphates	20.9
	Peroxide of Iron	8.8
	Lime	1.5
	Sulphate of Lime (Plaster)	3.1
	Chloride of Potassium	trace
	Silica	63.7
	Loss	2.0
		100.0

No. XXI.

COMPARATIVE VALUE OF THE URINE OF DIFFERENT ANIMALS.

	Solid Matter.		
	Organic.	Inorganic.	Total.
Man	23.4	7.6	31
Horse	27.	33.	60
Cow	50.	20.	70
Pig	56.	18.	74
Sheep	28.	12.	40

No. XXII.

GUANO.

Water	6.40
Ammonia	2.71
Uric Acid	34.70
Oxalic Acid, etc.	26.79
Fixed Alkaline Salts.	
Sulphate of Soda	2.94
Phosphate of Soda	.48
Chloride of Sodium (salt)	.86
Earthy Salts.	
Carbonate of Lime	1.36
Phosphates	19.24
Foreign Matter.	
Silicious grit and sand	4.52
	100.00

Composition of Fresh Farm-yard Manure, (composed of Horse, Pig, and Cow Dung, about 14 days old). Analysis made Nov. 3d, 1854, by Dr. Augustus Voelcker, Professor of Chemistry in the Royal Agricultural College, Cirencester, England:

Water		66.17
Soluble Organic Matter		2.48
* Soluble Inorganic Matter (Ash)—		
Soluble Silica (silicic acid)	.237	
Phosphate of Lime	.299	
Lime	.066	
Magnesia	.011	
Potash	.573	

* Containing Nitrogen .... .149
Equal to Ammonia .... —— .181

Chloride of Sodium	.030	
Carbonic Acid and loss	.218	
	——	1.54
*Insoluble Organic Matter		25.76
Insoluble Inorganic Matter (Ash)—		
Soluble Silica } silicic acid	.967	
Insoluble Silica } silicic acid	.561	
Oxide of Iron, Alumina, with Phosphates	.596	
(Containing Phosphoric Acid, .178)		
(Equal to bone earth, .386)		
Lime	1.120	
Magnesia	.143	
Potash	.099	
Soda	.019	
Sulphuric Acid	.061	
Carbonic Acid and loss	.484	
	——	4.05
		100.00

According to this analysis one ton (2,000 lbs.) Farm-yard Manure contains—

Soluble Silica (silicic acid)	24	lbs.
Ammonia (actual or potential)	$15\frac{3}{5}$	"
Phosphate of Lime	$13\frac{7}{10}$	"
Lime	$23\frac{7}{10}$	"
Magnesia	$3\frac{1}{10}$	"
Potash	$13\frac{1}{2}$	"
Soda	$1\frac{2}{5}$	"
Common Salt	$\frac{6}{10}$	"
Sulphuric Acid	$2\frac{1}{3}$	"
Water	$1323\frac{2}{5}$	"
Woody Fibre, etc.	579	"

Of course no two samples of Farm-yard Manure are exactly of the same composition. That analyzed by Dr. Voelcker was selected with much care, as representing a fair average.

GREEN SAND MARL (OF NEW JERSEY).

Protoxide of Iron	15.5
Alumina	6.9
Lime	5.3
Magnesia	1.6
Potash	4.8

* Containing Nitrogen	.494	
Equal to Ammonia	——	.599
The whole Manure contains Ammonia in a free state		.034
" " " " " in the form of salts		.089

Soluble Silica	32.4
Insoluble Silica and Sand	19.8
Sulphuric Acid	.6
Phosphoric Acid	1.3
Water	8.0
Carbonic Acid, etc	3.8
	100.0

This is an average of three analyses copied from Prof. Geo. H. Cook's report of the Geology of New Jersey. According to this estimate one ton (2000 lbs.) of Green Sand Marl contains—

Lime	106 lbs.
Magnesia	32 "
Potash	96 "
Soluble Silicic Acid	648 "
Sulphuric Acid	12 "
Phosphoric Acid	26 "

(Equal to Phosphate of Lime 56½ lbs.)

For the analysis of fertile and barren soils, see page **63.**

THE PRACTICAL FARMER.

THE PRACTICAL FARMER.

Who is the *practical farmer?* Let us look at two pictures and decide.

Here is a farm of 100 acres in ordinary condition. It is owned and tilled by a hard-working man, who, in the busy season, employs one or two assistants. The farm is free from debt, but it does not produce an abundant income; therefore, its owner cannot afford to purchase the best implements or make other needed improvements; besides, he don't *believe* in such things. His father was a good solid farmer; so was his grandfather; and so is he, or he thinks he is. He is satisfied that "the good old way" is best, and he sticks to it. He works from morning till night; from spring till fall. In the winter he *rests*, as much as his lessened duties will allow. During this time, he reads little, or nothing. Least of all does he read about farming. He don't want to learn how to dig potatoes out of a book. Book farming is nonsense. Many other similar ideas keep him from agricultural reading. His house is comfortable, and his barns are quite as good as his neighbors', while his farm gives him a living. It is true that his soil does not produce as much as it did ten years ago; but prices are better, and he is satisfied.

Let us look at his premises, and see how his affairs are managed. First, examine the land. Well, it is good fair land. Some of it is a little springy, but it is not to be called *wet*. When first laid down, it will produce a ton and a half of hay to the acre—it used to produce two tons. There are some stones on the land, but not enough, in his estimation, to do harm. The plowed fields are pretty good; they will produce 35 bushels of corn, 13 bushels of wheat, or 30 bushels of oats per acre, when the season is not dry. His father used to get more; but, somehow, the *weather* is not so favorable as it was in old times. He has thought of raising root crops, but they take more labor than he can afford to hire. Over in the back part of the land there is a muck-hole, which is the only piece of *worthless* land on the whole farm.

Now, let us look at the barns and barn-yards. The stables are pretty good. There are some wide cracks in the siding, but they help to ventilate, and make it healthier for the cattle. The manure is thrown out of the back windows, and is left in piles under the eaves of the barn. The rain and sun make it nicer to handle. The cattle have to go some distance for water; and this gives them exercise. All of the cattle are not kept in the stable; the fattening stock are kept in the various fields, where hay is fed out to them from the stack. The barn-yard is often occupied by cattle, and is covered with their manure, which lies there until it is carted on to the land. In the shed are the tools of the farm, consisting of carts, plows—not deep plows: this farmer thinks it best to have roots near the surface of the soil where they can have the benefit of the sun's heat, —a harrow, hoes, rakes, etc. These tools are all in good order; and, unlike those of his less prudent neighbor, they are protected from the weather.

The crops are cultivated with the plow and hoe, as they have been since the land was cleared, and as they always will be until this man dies.

Here is the 'practical farmer' of the present day. Hard working, out of debt, and economical,—of dollars and cents, if not of soil and manures. He is a better farmer than two-thirds of the three million farmers in the country. He is one of the best farmers in his town—there are but few better in the county, not many in the State. He represents the better average class of his profession.

With all this, he is, in matters relating to his business, an unreading, unthinking man. He knows nothing of the first principles of farming, and is successful by the *indulgence* of nature, not because he understands her, and is able to make the most of her assistance.

This is an unpleasant fact, but it is one which cannot be denied. We do not say this to disparage the farmer, but to arouse him to a realization of his position, and of his power to improve it.

But let us see where he is wrong.

He is wrong in thinking that his land does not need draining. He is wrong in being satisfied with one and a half tons of hay to the acre when he might easily get two and a half. He is wrong in not removing as far as possible every stone that can interfere with the deep and thorough cultivation of his soil. He is wrong in reaping less than his father did, when he should get more. He is wrong in ascribing to the weather, and similar causes, what is due to the actual impoverishment of his soil. He is wrong in not raising turnips, carrots, and other roots, which his winter stock so much need, when they might be raised at a cost of less than one-third of their value as food. He is wrong in considering worthless a deposit of muck, which is a mine of wealth if properly employed. He is wrong in *ventilating* his stables at the cost of *heat*. He is wrong in his treatment of his manures, for he loses more than one half of their value from evaporation, fermentation, and leaching. He is wrong in not having water at hand for his cattle—their exercise detracts from their accumulation of fat and the economy of their heat, and it exposes them to cold. He is wrong in not protecting his fattening stock from the cold of winter; for, under exposure to cold, the food, which would otherwise be used in the formation of *fat*, goes to the production of the animal heat necessary to counteract the chilling influence of the weather, p. 44. He is wrong in allowing his manure to lie unprotected in the barn-yard. He is wrong in not adding to his tools the deep surface plow, the sub-soil plow, the cultivator, and many other implements of improved construction. He is wrong in cultivating with the plow and hoe, those crops which could be better or more cheaply managed with the cultivator or horse-hoe. He is wrong in many things more, as we shall see if we examine all of his yearly routine of work. He is right in a few things; and but a few, as he himself would admit, had he that knowledge of his business which he could obtain in the leisure hours of a single winter. Still he thinks himself a *practical* farmer. In twenty years, we shall have fewer such, for our young men have the mental capacity and mental energy necessary to raise them to the highest point of practical education, and to that point they are gradually but surely rising. We have far fewer now than twenty years ago.

Let us now place this same farm in the hands of an educated and understanding cultivator; and at the end of five years, look at it again:

He has sold one half of it, and cultivates but fifty acres. The money for which the other fifty were sold has been used in the improvement of the farm. The land has all been under-drained, and shows the many improvements consequent on such treatment. The stones and small rocks have been removed, leaving the surface of the soil smooth, and allowing the use of the sub-soil plow, which, with the under-drains, has more than doubled the productive power of the farm. Sufficient labor is employed to cultivate with improved tools, extensive root crops, and they invariably give a large yield. The grass land produces a yearly average of 2½ tons of hay per acre. From 80 to 100 bushels of corn, 30 bushels of wheat, and 45 bushels of oats are the average of the crops reaped. The soil has been put in the best possible condition, while it is regularly supplied with manures containing everything taken away in the abundant crops. The principle that all earthy matters sold away must be bought back again, is never lost sight of in the regulation of crops and the application of manures. The *worthless* muck-bed was retained, and is made worth a dollar a load to the compost-heap, especially as the land requires an increase of organic matter. A new barn has been built large enough to store all of the hay produced on the farm. It has stables, which are tight and warm, and are well ventilated *above* the cattle. The stock being thus protected from the loss of their heat, give more milk, and make more fat on a less amount of food than they did under the old system. Water is near at hand, and the animals are not obliged to over-exercise. The manure is carefully composted, either under a shed constructed for the purpose with a tank and pump, or is thrown into the cellar below, where the hogs mix it with a large amount of muck, which has been carted in after being thoroughly decomposed by the lime and salt mixture.

They are thus protected against all loss, and are prepared for the immediate use of crops. No manures are allowed to lie in the barn-yard, but they are all early removed to the compost heap, where they are preserved by being mixed with carbonaceous matter. In the tool shed, we find deep surface-plows, sub-soil plows, cultivators, horse-hoes, seed-drills, and many other valuable implements.

This farmer takes one or more agricultural papers, from which he learns new methods of cultivation, while his knowledge of the *reasons* of various agricultural effects enables him to discard the injudicious suggestions of mere *book farmers* and uneducated dreamers.

Here are two specimen farmers. Neither description is over-drawn. The first is much more careful in his operations than the majority of our rural population. The second is no better than many who may be found in America.

We appeal to the common sense of the reader of this work to know which of the two is the *practical farmer*—let him imitate either, as his judgment shall dictate.

FINIS.

EXPLANATION OF TERMS.

ABSORB—to soak up a liquid or gas, or to take substances from air or from watery solutions.
ABSTRACT—to take from.
ACID—sour; a sour substance.
AGRICULTURE—the art of cultivating the soil.
ALKALI—the direct opposite of an *acid*, with which it has a tendency to unite.
ALUMINA—the base of clay.
ANALYSIS—separating into its primary parts any compound substance.
CARBONATE—a compound, consisting of carbonic acid and an alkali.
CAUSTIC—burning.
CHLORIDE—a compound containing chlorine.
CLEVIS—that part of a plow by which the drawing power is attached.
DECOMPOSE—to separate the constituents of a body from their combinations, forming simple substances into new compounds.
DIGESTION—the decomposition of food in the stomach and intestines of animals (agricultural).
DEW—deposit of the insensible vapor of the atmosphere on cold surfaces.
EXCREMENT—the matter given out by the organs of plants and animals, being those parts of their food which they are unable to assimilate.
FERMENTATION—a kind of decomposition.
GAS—air—aeriform matter.
INGREDIENT—component part.
INORGANIC—mineral, or earthy, not organized by animal or vegetable life.
MOULDBOARD—that part of the surface plow which turns the sod.
MULCHING—covering the soil with litter, leaves, or other refuse matter. See p. 212.
NEUTRALIZE—to overcome the characteristic properties or effects of.
ORGANIC MATTER—that kind of matter which possesses or has possessed an organized (or living) form.
OXIDE—a compound of oxygen with metal.
PHOSPHATE—a compound of phosphoric acid with an alkali.
PUNGENT—pricking.
PUTREFACTION—rotting.
SATURATE—to *fill* the pores of any substance, as a sponge with water, or charcoal with ammonia.
SILICATE—a compound of silicic acid with an alkali.
SOLUBLE—capable of being dissolved.
SOLUTION—a liquid containing another substance dissolved in it.
SATURATED SOLUTION—one which contains as much of the foreign substance as it is capable of holding.
SPONGIOLES—the absorbent ends of roots.
SULPHATE—a compound of sulphuric acid with an alkali.
VAPOR—(see "gas").