GEORGE EDWIN WARING

THE ELEMENTS OF AGRICULTURE

George Edwin Waring

The Elements of Agriculture

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The Elements of Agriculture / A Book for Young Farmers, with Questions Prepared for the Use of Schools:

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ELEMENTS
OF
AGRICULTURE

Extract from a letter to the author from Prof. Mapes, editor of the *Working Farmer*:

> * * * "After a perusal of your manuscript, I feel authorized in assuring you that, for the use of young farmers, and schools, your book is superior to any other elementary work extant. JAMES J. MAPES."

Letter from the Editor of the N. Y. Tribune:

> My Friend Waring,
> If all who need the information given in your *Elements of Agriculture* will confess their ignorance as frankly as I do,

and seek to dispel it as promptly and heartily, you will have done a vast amount of good by writing it. * * * * * I have found in every chapter important truths, which I, as a would-be-farmer, needed to know, yet which I *did not* know, or had but a confused and glimmering consciousness of, before I read your lucid and straightforward exposition of the bases of Agriculture as a science. I would not have my son grow up as ignorant of these truths as I did for many times the price of your book; and, I believe, a copy of that book in every family in the Union, would speedily add at least ten per cent. per acre to the aggregate product of our soil, beside doing much to stem and reverse the current which now sets so strongly away from the plow and the scythe toward the counter and the office. Trusting that your labors will be widely regarded and appreciated,

I remain yours truly,

HORACE GREELEY.

New York, June 23, 1854.

TO THE STUDENT

This book is presented to you, not as a work of science, nor as a dry, chemical treatise, but as a plain statement of the more simple operations by which nature produces many results, so common to our observation, that we are thoughtless of their origin. On these results depend the existence of man and the lower animals. No man should be ignorant of their production.

In the early prosecution of the study, you will find, perhaps, nothing to relieve its tediousness; but, when the foundation of agricultural knowledge is laid in your mind so thoroughly that you know the character and use of every stone, then may your thoughts build on it fabrics of such varied construction, and so varied in their uses, that there will be opened to you a new world, even more wonderful and more beautiful than the outward world, which exhibits itself to the senses. Thus may you live two lives, each assisting in the enjoyment of the other.

But you may ask the *practical* use of this. "The world is made up of little things," saith the proverb. So with the productive arts. The steam engine consists of many parts, each part being itself composed of atoms too minute to be detected by our observation. The earth itself, in all its solidity and life, consists entirely of atoms too small to be perceived by the naked eye, each visible particle being an aggregation of thousands of constituent elements. The crop of wheat, which the farmer raises by his labor, and sells for money, is produced by a combination of particles equally small. They are not mysteriously combined, nor irregularly, but each atom is taken from its place of deposit, and carried to its required location in the living plant, by laws as certain as those which regulate the motion of the engine, or the revolutions of the earth.

It is the business of the practical farmer to put together these materials, with the assistance of nature. He may learn her ways, assist her action, and succeed; or he may remain ignorant of her operations, often counteract her beneficial influences, and often fail.

A knowledge of the *inner* world of material things about us will produce pleasure to the thoughtful, and profit to the practical.

SECTION FIRST.
THE PLANT

CHAPTER I

INTRODUCTION

What is the object of cultivating the soil?
What is necessary in order to cultivate with economy?
Are plants created from nothing?

The object of cultivating the soil is to raise from it 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 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 where this is to be obtained, which 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 formed.

> What must we do to learn the composition of plants?
> What takes place when vegetable matter is burned?
> What do we call the two divisions produced by burning?
> Where does organic matter originate? Inorganic?
> How much of chemistry should farmers know?

If we burn any vegetable substance it disappears, except a small quantity of earthy matter, which we call *ashes*. In this way we make an important division in the constituents of plants. One portion dissipates into the atmosphere, and the other remains as ashes.

That part which burns away during combustion is called *organic matter*; the ashes are called *inorganic matter*. The organic matter has become air, and hence we conclude that it was originally obtained from air. The inorganic matter has become earth, and was obtained from the soil.

This knowledge can do us no good except by the assistance of chemistry, which explains the properties of each part, and teaches us where it is to be found. It is not necessary for farmers to become chemists. All that is required is, that they should know enough of chemistry to understand the nature of the materials of which their crops are composed, and how those materials are to be used to the best advantage.

This amount of 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 children the first principles of agriculture: and it contains all that is absolutely necessary to an understanding of the practical operations of cultivation, etc.

> Is organic matter lost after combustion?
> Of what does it consist?
> How large a part of plants is carbon?

We will first examine the *organic* 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 often less than one part in one hundred of their dry weight.

> What do we mean by gas?
> Does oxygen unite with other substances?
> Give some instances of its combinations

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 organic part consists of the three gases named above. By the word gas, we mean *air*. Oxygen, hydrogen and nitrogen, when pure, are always 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 gray 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 of the 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 agriculture, will be considered in the following pages.

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

CHAPTER II

ATMOSPHERE

What is atmospheric air composed of?
In what proportions?
What is the use of nitrogen in air?
Does the atmosphere contain other matters useful to vegetation?
What are they?

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 accelerated, and animals would be so stimulated that death would soon ensue. The 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

What is the source of the carbon of plants?
What is carbonic acid?
What is its proportion in the atmosphere?
Where else is it found?
How does it enter the plant?
What are the offices of leaves?

Carbonic acid is in all probability the only source of the carbon of plants, and consequently is of more importance 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 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: that of absorbing carbonic acid from the atmosphere—that of assisting in the chemical preparation of the sap—and that of 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. Usually, the pores on the under side of the leaf 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 no such action. Young sprouts may have the power of absorbing and decomposing carbonic acid.

> What parts of roots absorb food?
>
> How much of their carbon may plants receive through their roots?
>
> What change does carbonic acid undergo after entering the plant?
>
> In what parts of the plant, and under what influence, is carbonic acid decomposed?

The roots of plants terminate at their ends in minute spongioles, or mouths for the absorption of fluids containing nutriment. In these fluids there exist greater or less quantities of carbonic acid, and a considerable amount of this gas enters into the circulation of the plants and is carried to those parts where it is required for decomposition. Plants, under favorable circumstances, may thus obtain about one-third of their carbon.

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 reperform 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.

> Explain the condition of different latitudes.
>
> Does the proportion of carbonic acid in the atmosphere remain about the same?

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 eight or nine months of the 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 $^1/_{2500}$ 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 understated this, it becomes necessary for us to consider the means by which it is formed. Carbon, by the aid of fire, is made to unite 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. The respiration (or breathing) of animals is simply the union of the carbon of the blood 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.

> Explain some of the operations in which this reproduction takes place.
>
> How is it reproduced?

Furnaces are its wholesale manufactories. Every cottage fire is continually producing a new supply, and the blue smoke issuing from the cottage-chimney, as described by so many poets, possesses a new beauty, when we reflect that besides indicating a cheerful fire on the hearth, it 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 at 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 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, at the decay of either of these, the carbon which they contain must be again resolved into carbonic acid.

What are the coal-beds of Pennsylvania?
What are often found in them?

The coal-beds of Pennsylvania are mines of carbon once abstracted from the atmosphere by plants. In these coal-beds are often found fern leaves, toads, whole trees, and in short all forms of organized matter. These all existed as living things before the great floods, and 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 retained 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 an increased amount of vegetation.

> Explain the manner in which they become coal.
> How does the burning of coal benefit vegetation?
> Is carbon ever permanent in any of its forms?
> What enables it to change its condition?

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.

Give an instance of such change.
How do plants and animals benefit each other?
Describe the experiment with the glass tube.

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 is dissolved in 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

What is water composed of?
If analyzed, what does it yield?
How do plants obtain their hydrogen and oxygen?

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

Hydrogen and oxygen compose *water*, which, 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 is parted with usually 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 should not occupy our attention in this book.

NITROGEN

If vegetable matter be destroyed, what becomes of these constituents?

What is the remaining organic constituent?

Why is it worthy of close attention?

Do plants appropriate the nitrogen of the atmosphere?

Nitrogen, the only remaining *organic* 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 animal muscle.
3. It is often deficient in the soil.
4. It is liable to be easily lost from manures.

Although about four fifths of atmospheric air are pure nitrogen, it is almost certain that plants get no nutriment at all 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 of less importance than ammonia.

AMMONIA

What is the principal source from which they obtain nitrogen?

What is ammonia?

How is it formed?

Where does it always exist?

How do plants take up ammonia?

Ammonia is composed of nitrogen and hydrogen. It has a pungent smell and is familiarly known as *hartshorn*. The same odor is 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 usually unites with hydrogen, and forms ammonia. In consequence of this the atmosphere always contains more or less of this gas, arising from the decay, etc., which is continually going on all over the world.

This ammonia in the atmosphere is the capital stock to which all plants, not artificially manured, must look for their supply of nitrogen. As they can take up ammonia only through their roots, we must discover some means by which it may be conveyed from the atmosphere to the soil.

Does water absorb it?

What is *spirits of hartshorn*?
Why is this power of water important in agriculture?
What instance may be cited to prove this?

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.[1] This power of water has a direct application to agriculture, because the water constituting rains, dews, &c., 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

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

value of farm-yard and other animal manures, depends chiefly on the ammonia which they yield on decomposition. This subject, also the means for retaining in the soil the ammoniacal parts of fertilizing matters, will be fully considered in the section on manures.

> Can plants use more ammonia than is received from the atmosphere?
>
> On what does the value of animal manure chiefly depend?
>
> What changes take place after ammonia enters the plant?
>
> May the same atom of nitrogen perform many different offices?

After ammonia has entered the plant it may be decomposed, its hydrogen sent off, 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 he 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 lies on our table, 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.

> Is the same true of the other constituents of plants?
> Is any atom of matter ever lost?

The same is true of any of the organic or inorganic 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.

CHAPTER IV

INORGANIC MATTER

What are ashes called?

How many kinds of matter are there in the ashes of plants?

Into what three classes may they be divided?

What takes place when alkalies and acids are brought together?

We will now examine the ashes left after burning vegetable substances. This we have called inorganic matter, and it is obtained from the soil. Organic matter, although forming so large a part of the plant, we have seen to consist of four different substances. The inorganic portion, on the contrary, although forming so small a part, consists of no less than *nine* or *ten* different kinds of matter.[2] These we will consider in order. In their relations to agriculture they may be divided into *three* classes—*alkalies*, *acids*, and *neutrals*.[3]

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[2] Bromine, iodine, etc., are sometimes detected in particular plants, but need not occupy the attention of the farmer.

[3] 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 no decided alkaline or acid character.

Is the character of a compound the same as that of its constituents?

Give an instance of this.

Do neutrals combine with other substances?

Name the four alkalies found in the ashes of plants.

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 desire 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 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 often combine feebly 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

How may we obtain potash from ashes?
What are some of its agricultural uses?

When we pour water over wood ashes it dissolves the *potash* which they contain, and carries it through in solution. This solution is called *ley*, and if it be boiled to dryness it leaves a solid substance from which pure potash may be made. 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 silica (a neutral), 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.[4]

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

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[4] In some soils the *fluorides* undoubtedly supply plants with soluble silicates, as *fluoric acid* has the power of dissolving silica. Thus, in Derbyshire (England), where the soil is supplied with fluoric acid, grain is said never to lodge.

artificially applied, in smoothing the bark of fruit trees.

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

SODA

Where is soda found most largely?
What is Glauber's salts?
What is washing soda?
What are some of the uses of lime?

Soda, one of the alkalies contained in the ashes of plants, is very much the same as potash in its agricultural character. Its uses are the same as those of potash—before enumerated. 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. It is often necessary to render soils fertile.

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.

3. It corrects the acidity[5] of sour soils.

4. As chloride or sulphate of lime it is a good absorbent of fertilizing gases.

How is caustic lime made?
How much carbonic acid is thus liberated?
How does man resemble Sinbad the sailor?

In nature it usually exists 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, it is customary to burn the carbonate of lime in a kiln; by this means the carbonic acid is thrown off into the atmosphere and the lime remains in a pure or caustic state. A French chemist states that every cubic yard of limestone that is burned, throws off *ten thousand* cubic yards of carbonic acid, which may be used by plants. This reminds us of the story of Sinbad the sailor, where we read of the immense *genie* who came out of a very small box by the sea-shore, much to the surprise of Sinbad, who could not believe his eyes, until the *genie* changed himself into a cloud of smoke and went into the box again. Sinbad fastened the lid, and the *genie* must have remained there until the box was destroyed.

Now man is very much like Sinbad, he lets the carbonic acid out from the limestone (when it expands and becomes a gas); and

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[5] Sourness.

then he raises a crop, the leaves of which drink it in and pack the carbon away in a very small compass as vegetable matter. Here it must remain until the plant is destroyed, when it becomes carbonic acid again, and occupies just as much space as ever.

The burning of limestone is a very prolific source of carbonic acid.

MAGNESIA

> What do you know about magnesia?
> What is phosphoric acid composed of?
> With what substance does it form its most important compound?

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.

Magnesia is necessary to nearly all plants, but too much of it is poisonous, and it should be used with much care, as many soils already contain a sufficient quantity. It is often found in limestone rocks (that class called *dolomites*), and the injurious effects of some kinds of lime, as well as the barrenness of soils made from dolomites, may be attributed entirely to the fact that they contain too much magnesia.

ACIDS

PHOSPHORIC ACID

Phosphoric acid.—This subject is one of the greatest interest to the farmer. Phosphoric acid is composed of phosphorus and oxygen. The end of a loco-foco match contains phosphorus, and when it is lighted it unites with the oxygen of the atmosphere and forms phosphoric acid; this constitutes the white smoke which is seen for a moment before the sulphur commences burning. Being an acid, this substance has the power of combining with any of the alkalies. Its most important compound is with lime.

> Will soils, deficient in phosphate of lime, produce good crops?
>
> From what source do plants obtain their phosphorus?

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 the other earthy matters; 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 a small amount of *phosphorus*, which seems to be required in the formation of the seed.

SULPHURIC ACID

What is sulphuric acid composed of?
What is plaster?
What is silica?
Why is it necessary to the growth of plants?
What compounds does it form with alkalies?

Sulphuric acid is important to vegetation and is often needed to render soils 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 generally used in agriculture. Other important 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.

NEUTRALS

SILICA

How can you prove its existence in corn stalks?

What instance does Liebig give to show its existence in grass?

How do we supply silicates?

Why does grain lodge?

What is the most important compound of chlorine?

This is sand, the base of flint. It is necessary for the growth of all plants, as it gives them much of their strength. In connection with an alkali it constitutes the hard shining surface of corn stalks, straw, etc. Silica 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 it contains. Window glass is silicate of potash, rendered insoluble by additions of arsenic and litharge.

Liebig tells us that some persons 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 silica and potash which served to strengthen the grass.

There is always *enough* silica in the soil, but it is often necessary to add an alkali to render it available. When grain, etc., lodge or fall down from their own weight, it is altogether probable that they are unable to obtain from the soil a sufficient supply of the soluble silicates, and some form of alkali should be added to the soil to unite with the sand and render it soluble.

CHLORINE

> Of what use is chloride of lime?
> What is oxide of iron?
> What is the difference between the *per*oxide and the *prot*oxide of iron?

Chlorine is an important ingredient of vegetable ashes, and is often required to restore the balance to the soil. 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 best source from which to obtain both soda and chlorine. Chlorine unites with lime and forms *chloride of lime*, which is much used to absorb 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 grayish 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 nature, 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.

What can you say of the oxide of manganese?
How do you classify the inorganic constituents?

Oxide of Manganese, though often found in small quantities in the ashes of cultivated plants, cannot be considered indispensable.

Having now examined all of the materials from which the ashes of plants are formed,[6] 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.	Silica.
Soda.	Phosphoric "	Chlorine.
Lime.		Oxide of Iron.
Magnesia.		" Manganese.

[6] There is reason to suppose that *alumina* is an essential constituent of many plants.

CHAPTER V

GROWTH

Of what does a perfect young plant consist?

How must the food of plants be supplied?

Can carbon and earthy matter be taken up at separate stages of growth, or must they both be supplied at once?

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 (or tubes) which extend 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.

What seems to be nature's law with regard to this?

What is the similarity between making a cart and raising a crop?

In the growth of a young plant, what operations take place about the same time?

It is necessary that the materials of which plants are made should be supplied in certain proportions, and at the same time. 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 potash, and still has sufficient quantities of all of the other ingredients, the plant cannot take up these ingredients, because potash is 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 every thing 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.

What becomes of the carbonic acid?
How is the sap disposed of?
What does it contain?
How does the plant obtain its carbon?
Its oxygen and hydrogen?
Its nitrogen?
Its inorganic matter?

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, from various causes, is drawn up towards the leaves where it is evaporated. This water contains the *nitrogen* and the *inorganic matter* 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.
INORGANIC MATTER.	—	From the soil, and only *in solution* in water.

What changes does the food taken up by the plant undergo?

Many of the chemical changes which take place in the interior of the plant are well 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 formed into bone, muscle, fat, hair, etc., so in the plant the nutritive portions of the sap are resolved into wood, bark, grain, or some other necessary part.

The results of these changes are of the greatest importance in agriculture, and no person can call himself a *practical farmer* who does not thoroughly understand them.

CHAPTER VI

PROXIMATE DIVISION OF PLANTS, ETC

We have hitherto examined what is called the *ultimate* division of plants. That is, we have looked at each one of the elements separately, and considered its use in vegetable growth.

> Of what do wood, starch and the other vegetable compounds chiefly consist?
>
> Are their small ashy parts important?
>
> What are these compounds called?
>
> Into how many classes may proximate principles be divided?
>
> Of what do the first class consist? The second?
>
> What vegetable compounds do the first class comprise?

We will now examine another division of plants, called their *proximate division*. We know that plants 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 *organic* and *inorganic* ingredients described in the preceding chapters. They are made up almost entirely of *organic* matter, but their ashy parts, though very small, are (as we shall soon see) sometimes of great importance.

These compounds are called *proximate principles*,[7] or *vegetable proximates*. They 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*.

> Are these substances of about the same composition?
>
> Can they be artificially changed from one to another?
>
> Give an instance of this.
>
> Is the ease with which these changes take place important?
>
> From what may the first class of proximates be formed?

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 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 recollected by those who attended the Fair of the American Institute, in 1834, that Prof. Mapes exhibited samples of excellent sugar made from the juice of the cornstalk, starch, linen, and woody fibre.

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[7] By *proximate principle*, we mean that combination of vegetable elements which is known as a vegetable product, such as *wood*, etc.

The ease with which these proximates may be changed from one to the other is their most important agricultural feature, and should be clearly understood before proceeding farther. It is one of the fundamental principles on which the growth of both vegetables depends.

The proximates of the first class constitute usually the greater part of all plants, and they are readily formed from the carbonic acid and water which in nature are so plentifully supplied.

> Why are those of the second class particularly important to farmers?
>
> What is the general name under which they are known?
>
> What is the protein of wheat called?
>
> Why is flour containing much gluten preferred by bakers?
>
> Can protein be formed without nitrogen?
>
> If plants were allowed to complete their growth without a supply of this ingredient, what would be the result?

The *second class* of proximates, though forming only a small part of the plant, are of the greatest importance to the farmer, being the ones from which *animal muscle*[8] is made. They consist, as will be recollected, of carbon, hydrogen, oxygen and *nitrogen*, or of *all* of the organic 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*.

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[8] *Muscle* is *lean meat*, it gives to animals their strength and ability to perform labor.

The protein of wheat is called *gluten*—that of Indian 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.

What is the result if a field be deficient in nitrogen?

The protein 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 this constituent. To furnish this condition is the object of nitrogen given to plants as manure. If no *nitrogen* is supplied the protein substances cannot 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 *mineral* matters required in the formation of the ash, in a condition to be useful.

The wisdom of this provision is evident when we recollect that the protein substances are necessary to the formation of muscle in animals, for if plants were allowed to complete their growth without a supply of this ingredient, 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.[9]

ANIMALS

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

> Of what are the bodies of animals composed?
>
> What is the office of vegetation?
>
> What part of the animal is formed from the first class of proximates?
>
> From the second?
>
> Which contains the largest portions of inorganic matter, plants or animals?
>
> Must animals have a variety of food, and why?

Animals are composed (like plants) of organic and inorganic matter, and every thing necessary to build them up exists in plants. It seems to be the office 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 *proximates* (or compound substances) which we have just described.

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[9] This, of course, supposes that the soil is fertile in other respects.

In animals the compounds containing *no nitrogen* comprise the fatty substances, parts of the blood, etc., while the protein compound, or those which *do contain nitrogen*, form the muscle, a part of the bones, the hair, and other portions of the animal.

Animals contain a larger proportion of inorganic matter than plants do. Bones contain a large quantity of phosphate of lime, and we find other inorganic materials 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 be 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 the two kinds of proximates.

> Why is grain good for food?
>
> On what does the value of flour depend?
>
> Is there any relation between the ashy part of plants and those of animals?
>
> How may we account for unhealthy bones and teeth?

It is for this reason that grain, such as 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 soon explained.

What is a probable cause of consumption?
What is an important use of the first class of proximates?
What may lungs be called?
Explain the production of heat during decomposition.
Why is the heat produced by decay not perceptible?

Apart from the relations between the *proximate principles* of plants, and those of animals, there exists an important relation between their *ashy* or *inorganic* 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 by food, animals are prevented from the formation of 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.

Why is the heat produced by combustion apparent?
Explain the production of heat in the lungs of animals?
Why does exercise augment the animal heat?
Under what circumstances is the animal's own fat used in the production of heat?

The first class of proximates (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 of men and other animals may be called 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 liberation of *heat*, and the *intensity* of this heat depends on the *time* occupied in its *production*. In the case of decay, the chemical changes take place so slowly that the heat, being conducted away as soon as formed, is not perceptible 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 of animals the same law holds true. The blood contains matters belonging to this carbonaceous class, and they undergo in the lungs 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 animal necessities. When an animal 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 PROXIMATES AND VARIATIONS IN THE ASHES OF PLANTS

Of what proximate are plants chiefly composed?
What is the principal constituent of the potato root?
Of the carrot and turnip?
What part of the plant contains usually the most nutriment?

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

The stem or trunk of the plant or tree consists almost entirely 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*,[10] 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

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

explained by reference to the following figures, as described by Prof. Johnston:—

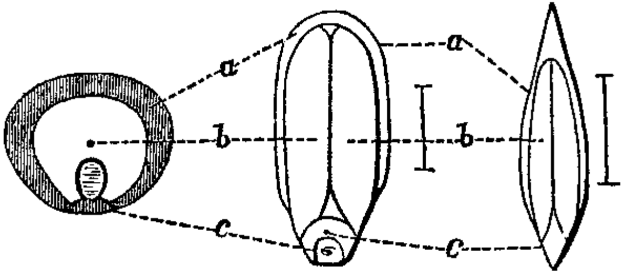

Fig. 1.

"Thus *a* shows the position of the oil in the outer part of the seed—it exists in minute drops, inclosed in six-sided cells, which consists 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."[11]

Is the composition of the inorganic matter of different parts of the plant the same, or different?

What is the difference between the ash of the straw and that of the grain of wheat?

The location of the *inorganic* part of plants is one of much interest, and shows the adaptation of each part to its particular

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[11] See Johnston's Elements, page 41.

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 silica and scarcely any phosphoric acid, while in that of the grain there is scarcely a trace of silica, although phosphoric acid constitutes more than one half of the entire weight. The leaves contain a considerable quantity of lime.

> What is the reason for this difference?
>
> In what part of the grain does phosphoric acid exist most largely?

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 *silica*, and the woody fibre which forms so large a proportion of the stalk. The silica is combined with an alkali, and constitutes the glassy coating of the straw. While the plant is young, this coating is 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 therefore requires but little phosphoric acid.

Why is Graham flour more wholesome than fine flour?
Are the ashes of all plants the same in their composition?

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 no necessity for strength, and as silica 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 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[12] 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 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.

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[12] Sifted through a fine cloth called a bolting cloth.

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, *silica*; of clover, *lime*; of beans, *potash*, etc. In grain, *potash* (or *soda*), etc., are among the important ingredients.

Of what advantage are these differences to the farmer?
Of what are plants composed?

These differences are of great importance to the practical farmer, as by understanding what kind of plants use 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 accurately.

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 *organic* and *inorganic* matter.

> What is organic matter? Inorganic?
> Of what does organic matter consist? Inorganic?
> How do plants obtain their organic food?
> How their inorganic?
> How is ammonia supplied? Carbonic acid?

Organic matter is that which burns away in the fire. Inorganic 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 inorganic matter of plants consists of potash, soda, lime, magnesia, sulphuric acid, phosphoric acid, chlorine, silica, oxide of iron, and oxide of manganese.

Plants obtain their organic 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 inorganic 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 profit.

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 combustion or decay, what becomes of their constituents?
> How does the inorganic matter enter the plant?
> Are the alkalies soluble in their pure forms?
> Which one of them is injurious when too largely present?
> How may sulphuric acid be supplied?
> Is phosphoric acid important?
> How must silica be treated?
> From what source may we obtain chlorine?

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 inorganic matters in the soil can enter the plant only when dissolved in 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 necessary 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 available only under certain conditions which will be described in the section on manures.

Silica is the base of 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.

> What is the difference between *per*oxide and *prot*oxide of iron?
>
> How must the food of plants be supplied?
>
> What takes place after it enters the plant?
>
> What name is given to the compounds thus formed?
>
> How are proximates divided?
>
> Which class constitutes the largest part of the plant?
>
> Of what are animals composed, and how do they obtain the materials from which to form their growth?

Oxide of iron is iron rust. There are two oxides of iron, the *peroxide* (red) and the *protoxide* (black). The former is a fertilizer, 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 inorganic, must be supplied in certain proportions, and at the time when it is required. In the plant, this food undergoes such chemical changes as are necessary to growth.

The compounds formed by these chemical combinations are called *proximates*.

Proximates 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 organic and inorganic matter, and their bodies are obtained directly or indirectly from plants.

> What parts of the animal belong to the first class of proximates?
>
> What to the second?
>
> What is necessary to the perfect development of animals?
>
> Why are seeds valuable for working animals?
>
> What other important use, in animal economy, have proximates of the first class?

Under what circumstances is animal fat decomposed?

The first class of proximates 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 both classes of proximates, and in the proportions required by their natures.

They require the phosphate of lime and other inorganic food which exist in plants.

Seeds are the best adapted to the uses of working animals, because they are rich in all kinds of food required.

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

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*.

Name the parts of the plant in which the different proximates exist.

State what you know about flour.

Do we know that different plants have ashes of different composition?

The *protein* and the *oils* of most plants exist most largely in the *seeds*.

The location of the proximates, as well as of the inorganic parts of the plant, show 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.

How are farmers to be benefited by such knowledge?

The facts contained in this chapter are the *alphabet of agriculture*, and the learner should not only become perfectly familiar with them, but should also clearly understand the *reasons* why they are true, before proceeding further.

SECTION SECOND.
THE SOIL

CHAPTER I

FORMATION AND CHARACTER OF THE SOIL

What is a necessary condition of growth?

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 therefore we will examine the nature of different soils, in order that we may understand the relations between them and plants.

What is a fixed character of soils?

How is the chemical character of the soil to be ascertained?

What do we first learn in analyzing a soil?

How do the proportions of organic or inorganic parts of soils compare with those of plants?

Of what does the organic part of soils consist?

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 the science of agriculture is able to point out these characteristics in all cases, so that we can ascertain from a scientific investigation what would be the chances for success in cultivating any soil which we examine.

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 organic and inorganic matter; but, unlike the plant, they usually possess much more of the latter than of the former.

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

> Can the required proportion be definitely indicated?
> From what source is the inorganic part of soils derived?
> Do all soils decompose with equal facility?
> How does frost affect rocks?
> Does it affect soils in the same way?

The organic part of soils consists of the same materials that constitute the organic part of the plants, and it 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 ten or fifty per cent.

The inorganic 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 not unimportant to the agriculturist; as by the same processes by which his soil was 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 as 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*[13] 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

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[13] The spaces between the particles.

will become much lighter, and can afterwards be worked with less difficulty.

What is the effect of water on certain rocks?

How are some rocks affected by exposure to the atmosphere? Give an instance of this.

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

What is the similarity between the composition of soils and the rocks from which they were formed?

What does feldspar rock yield? Talcose slate? Marls?

Does a soil formed entirely from rock contain organic matter?

How is it affected by the growth of plants?

Other actions, of a less simple kind, exert an influence on the stubbornness of rocks, and cause them to be resolved into soils.[14]

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[14] 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

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 feldspar, 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.[15] 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 inorganic or mineral 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.

What is the general rule concerning the composition of rocks?

Do these distinctions affect the fertility of soils formed from them?

What do we mean by the mechanical character of the soil?

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with sufficient power to burst the rock.

[15] Some rocks contain sulphur, phosphorus, etc., and these may, perhaps, be considered as organic matter.

Is its fertility indicated by its mechanical character?

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

> What is a sandy soil? A clay soil? A loamy soil? A marl? A calcareous soil? A peaty soil?

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 about 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.[16]

> How large a part of the soil may be used as food by plants?
>
> What do we learn from the analyses of barren and fertile soils?

We will now take under consideration that part of the soil on which depends its ability to supply food to the plant. This portion

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[16] These distinctions are not essential to be learned, but are often convenient.

rarely constitutes more than five or ten per cent. of the entire soil, sometimes 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 better 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
Silica (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

What can you say of the soils represented in the table of analyses?

What proportion of the fertilizing ingredients is required?

If the soil represented in the third column contained all the ingredients required except potash and soda, would it be fertile?

What would be necessary to make it so?

What is the reason for this?

What are the offices performed by the inorganic part of soils?

The soil represented in the first column might still be fertile with less organic matter, or with a larger proportion of clay (alumina), and less sand (silica). These affect its *mechanical*

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