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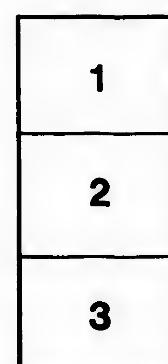

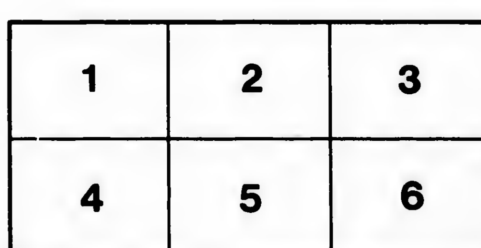

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Prescribe

AGRICULTURAL TEXT-BOOK FOR SCHOOLS.

FIRST PRINCIPLES

OF

AGRICULTURE.

BY

PROFESSOR TANNER, F.C.S.,

WITH INTRODUCTION, EXPLANATORY OF THE FIRST PRINCIPLES OF CHEMISTRY AND THE SYSTEM OF CHEMICAL NOMENCLATURE,

BY PROFESSOR LAWSON, Ph.D., LL.D., F.I.C.

Prescribed by the Council of Public Instruction for use in the Public School of Nova Scotia.

HALIFAX:
A. & W. MACKINLAY.
1880.

INTRODUCTION.

The Art of Agriculture is based upon the Science of Chemistry. There can be no intelligent cultivation of the soil without some knowledge of the leading principles of chemical science. The acquisition of such knowledge becomes possible, and indeed easy, when the pupil is made acquainted with the peculiarities of language and the nature of the formulæ and equations employed by chemists. An acquaintance with these modes of expression is required for the purpose of conveying chemical ideas with the necessary precision, and no attempt should be made to teach chemistry without their use.

The rules for the formation of Chemical Terms and Symbols, and for the construction of formulæ and chemical equations, are exceedingly simple; and chemical language and notation, instead of interposing difficulties in the pupil's way (as is feared by many persons), on the contrary, render clear and easily comprehensible what would otherwise appear obscure and confused. This is the sole reason why they are used.

The work of the Agriculturist is to convert matter in the soil, which would otherwise be useless to man, into useful crops, and to convert the whole, or a portion, of such crops, into flesh, wool, butter, and other animal products. The processes by which these conversions are accomplished depend upon chemical laws, according to which all changes of matter take place.

Matter, or material, of whatever nature or aspect, is either (1) *Simple*, consisting of one kind and not capable of yielding any other, or (2) *Compound*, that is, made up of two or more other kinds of matter which are simple. When a substance consists of only one kind of matter, it is said to be elementary, this ultimate form of matter is called an ELEMENT. The number of such Elements discovered up to the present time (February, 1880,) is eighty, of which sixty-four are Metals and sixteen Non-Metallic Elements, or, as they are sometimes called, Metalloids. The metals are mostly solid bodies at ordinary temperatures, one (Mercury) is liquid, and many of them can be converted into gases by heat. Certain of the non-metallic elements, Carbon, Sulphur, Phosphorus, &c., are likewise solid, one (Bromine) is liquid, and several (Hydrogen, Oxygen, Nitrogen, Chlorine) are gaseous at ordinary temperatures. Those that are solid or liquid can mostly be converted into gases by heat, and those that are gaseous can be condensed by pressure and lowering of temperature into liquids or solids. This difference of condition, whether the elements be solid, liquid or gaseous, does not necessarily represent a chemical difference.

Chemically the Elements may exist in two conditions, (1) In the free state, (2) Chemically combined. The atmosphere consists mainly of two gaseous Elements, Nitrogen and Oxygen, mixed mechanically, in the proportion of about four parts of the former to one of the latter. When thus mixed each Element retains its own properties unimpaired except by dilution. It is quite otherwise when the Elements combine chemically.

Two or more Elements chemically combined form a *Chemical Compound.* In such a compound certain properties of the Elements composing it are no longer displayed. The Elements, when they unite, counteract each other's activities as it were, and the compound acquires properties which the elements did not possess when free. Hydrogen is a gas; Oxygen is also a gas. When these two unite, heat and light are evolved, and a compound is produced, consisting of the two gases, but quite different from both in its properties. That compound is Water, which is chemically an Oxide of Hydrogen. It is not capable either of burning or of supporting combustion, but can unite with other oxides to form new and more complex compounds. Sodium is a soft shining metal, Chlorine a suffocating gas. When they combine the resulting compound is common salt.

All the Elements have Names by which they are distinguished, and the compounds formed by their union have likewise names expressive of their composition. Sodium and Chlorine, when they combine, form, as we have seen, common salt, the chemical name for which is Sodium Chloride, that is a compound of Sodium and Chlorine. Carbon (the most familiar form of which is charcoal) combines with Oxygen in two proportions, and the two resulting compounds are called repectively Carbon Monoxide, and Carbon Dioxide, to indicate that in the first there is one atom of Oxygen, and in the second two; this latter substance was first known as fixed air, and is still often called Carbonic Acid Gas, a name given to it before our present system of chemical nomenclature was made as perfect as it now is. A compound of Oxygen and one other Element is called an Oxide, of Chlorine and one other Element a Chloride, of Sulphur and another Element a Sulphide, of Iodine and another Element an Iodide, and so in other cases.

When the Oxide of a Non-metallic Element unites with water it forms *an acid,* that is a compound which has a sour taste and reddens litmus. When the Oxide of a metal combines with water on the other hand it forms *an alkali,* turning the red litmus blue.

When two such compounds, an alkali and acid, are brought together, their oxides unite, and a more complex compound is formed, which is neither acid nor alkaline, but neutral; it is usually soluble and crystallizable, and is called *A Salt.* Many of the compounds contained in the soil, in manures, and in food, are salts, or are built up in the same way. Land Plaster is Oxide of Calcium (Lime) combined with Sulphuric

Oxide, and is hence called Calcium Sulphate, by the Chemist; the same Oxide united with Carbon Dioxide forms Calcium Carbonate, common limestone or chalk. If the Carbon Dioxide be driven off from this latter by heat the Calcium Oxide remains as burnt lime; when water is now added it combines with the Oxide and forms the Alkaline Hydrate. Calcium Oxide united with Phosphoric Oxide forms Calcium Phosphate or Phosphate of Lime. Clay consists essentially of Aluminium Oxide and Silicic Oxide, that is Aluminium Silicate, which, altho' it corresponds to a salt in composition, is, like many other Silicates, not soluble in water.

The Elements when in union with each other always so exist in definite proportions by weight and volume. They unite (with very few exceptions) in equal volumes compared in the gaseous state. But the volume or atomic proportion, although always constant in weight for the same element, is different in weight for the different elements. One volume or atomic proportion of Hydrogen (which is the lightest element) is reckoned as weighing 1, and a volume or atomic proportion of Oxygen weighs 16, one of N. 14, one of Sulphur 32; these are the atomic weights of the elements respectively. Each element has a definite atomic weight.

As the atomic proportion or "atom" of an element has a definite weight, so a compound also has its definite or molecular weight. Two atoms or volumes of Hydrogen, weighing 1 each, unite with one atom or volume of Oxygen, weighing 16, to form one molecule of Water weighing 18. The molecular weight of a compound is the sum of the atomic weights of its constituents.

In Chemical Notation every element is indicated by a *Symbol*, which consists, in most cases, of the initial letter of the name of the element, as C for Carbon; where two or more elements have the same initial letter, an additional distinctive letter is added when necessary, as Cl for Chlorine. The symbol stands for one atomic proportion, that is one volume or "atom," of the element; this is multiplied by placing a small figure on the right hand side of the symbol, thus, Cl_2.

A *Formula* is simply formed by placing two or more symbols together, to show the elements of which a compound consists. Thus H_2O is the formula for Water, showing that this compound consists of two volumes of Hydrogen and one volume of Oxygen; as the atomic weight, or weight of one volume, of Hydrogen is 1, the two atoms will weigh 2, and as the atomic weight of Oxygen is 16, its one volume will weigh 16;—the formula thus represents to us the exact proportions by volume and weight of the elements of which the compound consists. The use of a chemical formula is to show the precise composition of a compound body.

A *Chemical Equation* consists of two or more formulæ, or of at least one formula and two or more symbols; its object is to represent what is called a "reaction," that is a change in the constitution, or arrangement of the components, of a compound, or the formation from free elements of a compound, or the resolution of a compound more or less completely into its elements. Thus, if we place a piece of the element Sodium in contact with the compound Water, a chemical change takes place: the sodium and water have combined to form an alkali, but not the whole of the water, for a gas, H, is set free. The change is explained by the following "equation:"—

$$2\ H_2O + Na_2 = 2\ NaOH + H_2$$

Which we may read thus: two molecules of Hydrogen Oxide (water) and two atoms of Sodium, *yield* two molecules of Sodium Hydrate and two atoms of Hydrogen. In every case where the algebraic sign of equality = is used in a chemical equation it is to be read, not as "equal to," (which would suppress the essential idea sought to be conveyed), but as "*yields*" or "*yield*" so and so. For examples of chemical formulæ and equations, see foot notes on pages 35, 36, 37.

List of some Chemical Compounds mentioned in this work, with their formulæ.

Water .... H_2O
Silica (quartz, sand) .... $Si\ O_2$
Silicic Acid.............. $2H_2O,Si\ O_2$ or $H_4\ Si\ O_4$
Carbon Dioxide (Carbonic Acid Gas).......... CO_2
Sulphuric Acid (Oil of Vitriol) .... $H_2\ SO_4$
Phosphoric Oxide (Anhydride) .... P_2O_5
Phosphoric Acid .... $3H_2O$, P_2O_5, or H_3PO_4
Calcium Oxide (burnt lime) .... CaO
Calcium Hydrate (slacked lime)..CaO,H_2O or CaH_2O_2
Potassium Oxide............................ K_2O
Potassium Hydrate .... K_2O, H_2O or KHO
Sodium Oxide................................ Na_2O
Ammonia .... NH_3
Ferric Oxide .... Fe_2O_3
Sodium Chloride (common salt).............. NaCl
Calcium Carbonate (marble, limestone)
CaO, CO_2 or $CaCO_3$
Potassium Nitrate (Saltpetre) ..K_2O, N_2O_5 or KNO_3
Calcium Sulphate (Plaster, anhydrous)
CaO, SO_3 or Ca SO_4
Tri-Calcic Phosphate (bone earth)
3CaO, P_2O_5 or $Ca_3P_2O_8$
Bi-Calcic Phosphate (Reduced Phosphate)
2CaO H_2O, P_2O_5 or Ca_2H_2, 2 PO_4
Mono-Calcic Phosphate (Superphosphate)
CaO, 2 H_2O, P_2O_5 or Ca H_4, 2 P O_4
Aluminium Silicate, hydrated, (Silicate of Alumina, Clay)................ Al_2O_3, 2Si O_2, $2H_2O$
Aluminium and Potassium Silicate (Double Silicate of Alumina and Potash)....K_2O, Al_2O_3, 6 SiO_2

PREFACE TO THE FIRST EDITION.

In the preparation of this elementary work upon the Principles of Agriculture, the author has been desirous of avoiding, as far as possible, the use of technical terms, in cases where other terms in general use would convey the same idea. When it has been necessary to employ such terms, they have been explained in the simplest possible manner, so as to render the book intelligible to all classes of readers. Although the work is strictly elementary, the author has considered it desirable to draw attention to certain points in practice and in theory, which seem to be insufficiently recognized by many of our practical and scientific agriculturists.

London, January, 1878.

PREFACE TO THE SECOND EDITION.

The rapid sale of a large edition, and the favourable opinions which have been expressed of its utility, encourage the hope that the "First Principles of Agriculture" has not only been found useful for pupils under instruction in the elementary stage of Agricultural Science, but of value to those who desire to inform themselves on the subject. The alterations which have been made in the Second Edition will probably increase its utility.

London, December. 1879.

CONTENTS.

FIRST PRINCIPLES OF AGRICULTURE.

CHAPTER I.

THE SOIL.

1. **The cultivation of the soil** is commonly known as **Agriculture**, and the term usually includes the several operations and the general system of management whereby the farmer is enabled to grow corn, meat, wool, and various other marketable products. The success of his work is determined by his producing as large a supply as possible from the land, at the smallest cost to himself, and with the least injury to the soil. The object of the present work is to explain in familiar language some of the circumstances which influence these results.

2. The surface of the land consists of earthy matter, more or less finely broken, and this is called **the soil.** This may be termed the raw material which the farmer has to manufacture into products suitable for food and clothing. He uses the soil for these purposes, calling to his aid the agencies of animal and vegetable life, and the stores of fertility which are present in the atmosphere.

3. In some cases the soil is very shallow, and if you dig a hole in the ground you will soon reach the hard rock. In other instances there is a very considerable depth of earth; and thus we have both **shallow** and **deep soils.**

4. When a hole is dug into a deep soil—especially if it be what is known as a clay soil—we observe a marked change in the general appearance of the soil

some little distance below the surface: sometimes it is a difference of colour, sometimes a variation in the roughness, but whatever the difference may be, it is clear to the eye that there is a difference in the character of the soil. The portion that so differs from the surface soil is called the **sub-soil,** or under-soil. In speaking of the upper or surface soil we usually call it the soil, and that portion which lies below it is known as the sub-soil.

5. The question naturally arises, how is it that the land is thus covered by this earthy matter, and **whence did the soil come?** Soils are produced by the breaking up or crumbling of rocks. If a rock were reduced into powder either by grinding, or by any other mechanical means, that pulverized rock would be a soil. But soils are not formed by rocks being pulverized by man's industry ; natural agencies carry out this work very perfectly, sometimes with, and at other times without, our co-operation.

6. There are **three agencies** which thus turn rocks into soil, and thereby produce for the farmer the earth from which he makes his crops to grow. Water is one of these agents. If water falls upon or soaks into a piece of rock, it has a tendency to dissolve some portion of the stone, and then pass away with its spoil as soon as other water is ready to take its place. Thus, rocks are softened by **water** and some portions dissolved out of them.

7. Water also acts powerfully because it contains some **atmospheric air** in it. Rain-water in falling through the air takes into, and amongst its particles, some portion of the air through which it passes, and retains it. Thus water has generally some atmospheric air in it. This air is a mixture of two gases—oxygen and nitrogen—with some others in small proportions, but of the latter we now only notice one, carbonic acid.

8. When water carries into a rock the oxygen which it contains, this gas has a tendency to form chemical

combinations with some of the materials in the rock. When carbonic acid is also present it helps to dissolve in the water, portions of the rock which would not have been soluble in pure water. Thus the solvent action of water and its **associated gases** dissolves out certain portions of the rock, and thereby the rock has holes made in it, which gradually increase in size, and thus expose a larger surface to be subsequently acted upon by further supplies of water.

9. There is a third agency which exerts its influence, and often does so with great force, that is, **frost.** When the surface of a rock has been penetrated by water, and the temperature of the air falls below the freezing point, the water becomes frozen. As water freezes it gets bigger, and the particles of a wet rock are pushed apart so as to make room for the water which is freezing. When the frost has ceased and a thaw takes place, portions of the surface, being thereby released from the solid bands of ice, are thrown off from the rock. The extent to which this takes place depends in a great measure upon the size of the holes which the water and gases may have made in the rock. Sometimes the openings scarcely penetrate below the surface, and in such cases the surface of the rock only is affected; at other times large masses of rock are thrown off.

10. These three agents wear away our hardest rocks, and thus they are broken down and pulverized into soil. Softer rocks are of course acted upon more rapidly than hard rocks, but every rocky surface is thus made to yield its contribution to the soil. The lower forms of vegetation then establish themselves on this newly-made soil, and their rootlets penetrate and obtain their food from it. In due course these plants die, and add decaying matter to the soil, which thereby becomes fitted for the support of higher forms of vegetation, and these prepare the way for those of still higher organisation.

11. If soils so formed were allowed to remain where they were first produced, we should find very little difference between those soils and the rocks from which they were formed, except so far as regards their being in a more broken condition. But the study of geology shows that great changes have taken place on the surface of the globe, and that when soils have thus been formed from rocks, they have frequently been washed away and mixed with soils produced from other rocks. Soils of this character are often found in our valleys, and are distinguished as **alluvial soils.** In many cases these mixed soils have been again formed into rocks, and after long periods of time, these rocks have again become converted into soil. Animal and vegetable life have also exerted very great influences upon the character of many of these reconstructed rocks. Thus our soils differ very much in character and composition, according to the varying character of the rocks from which they may have been produced, and also according as they may have been more or less intermixed with other soils.

12. There are some soils which are not produced by these means, such as **Peaty Soils.** These consist of vegetable matter which has grown and decayed, generally in the place where these soils are found. Their mode of production is peculiar. They are generally found in places from which the water cannot easily pass away. Here aquatic vegetation and mosses establish themselves, and as they require a liberal supply of water for their growth, they flourish luxuriantly. Growth after growth takes place, decaying matter accumulates, which encourages further growth, so that ultimately the rising bed of peat is held only in check by the supply of water. When they have grown up as high as the water allows them to grow, tougher and more woody plants establish themselves; these give the harder and firmer surface which is found upon our peat bogs and mosses.

13. These peaty soils therefore differ essentially from the soils which have been produced by the pulverization or powdering of rocks. Peat soils consist almost entirely of vegetable matter, which often reaches as much as 97 per cent., and they contain very little mineral matter; whilst soils produced from rocks are chiefly composed of mineral matter, and have only a small proportion of vegetable matter.

14. For the convenience of being able to describe with accuracy the character of soils, so that soils of the same character may be called by the same names, it has become necessary to classify soils according to their texture and condition, as well as by their composition. The character is indicated by a mechanical analysis, and the composition is determined by chemical analysis. By these means we can inform ourselves with great accuracy as to the composition and character of any soil, and establish a regular classification.

15. The **mechanical analysis** of soils is largely based upon the proportions of clay and sand which they contain. The term **Clay** is applied to the finer portions of the mineral matter of the soils. These portions have by various means become so reduced in size that they are perfectly soft to the touch, and when pressed in the hand retain the form into which they may be moulded or pressed. The clay which is used for making bricks and pottery is familiar to every one. It is soft and easily moulded in the hand, and when water is placed in any hollow on its surface the water does not readily soak away.

16. **Sand** is just the reverse. It really consists of very minute stones, and when pressed in the hand it is gritty and hard to the touch. If any attempt be made to mould it into any particular shape, it does not keep the form so given to it. If a hollow be made on the surface and water be poured into it, the water quickly passes through it. In the sand upon the sea-shore we have a familiar example of the sand in soils.

17. These two portions of the soil are strikingly distinct, and they are therefore used as the foundation of a system upon which we can base a general **classification of soils.** The manner in which the quantity of clay and sand in a soil is determined is exceedingly simple. When a sample of soil is to be so examined, measures are taken to separate the stones and portions of rock which are present. These are not a part of the true soil; they are simply rock or stone mixed with the soil. The soil upon which the farmer has to rely for his crops is the fine earthy matter, and not the stones which are mixed with it. It would, however, be a serious error to consider these stones and pieces of rock as useless to the farmer. These have their duties to perform, as we shall hereafter see; but, for the present purpose, they must be distinguished from the soil which has to be examined.

18. To obtain the fine earthy matter from a soil, a small sieve or piece of wire work should be used, and the coarser portions thereby separated and carefully dried. Two hundred grains of the sifted soil may then be thoroughly mixed with about half a pint of water, and well shaken for some few minutes. As soon as this has been accomplished, the vessel may be allowed to remain quiet for a short time, during which the sand falls to the bottom. Whilst the fine particles of clay are still floating in the water, it should be quickly poured into another vessel, leaving the sand behind in the first. If the clay be not entirely removed in the first attempt, the sand may be again washed, and any clay poured into the vessel containing that first removed. You have thus made a separation of the soil, which will enable you to determine its character, and to classify it accordingly. More advanced and accurate processes are sometimes adopted (see Professor Church's "Laboratory Guide"), but this simple process gives results which are sufficiently satisfactory for all ordinary purposes.

19. The sand and clay are afterwards carefully dried nd weighed. If you found the weight of sand equal o the weight of clay, this would represent, in other ords, 50 per cent. of sand. A soil of this composition known as a **Loam**, as shown in the following able:—

Name of Soil.	Percentage of Sand.
Sand, ...	80 to 100
Loam, . .	40 to 60
Clay, ...	— to 20

It is necessary, however, to arrange for other proportions of clay and sand, and these are distinguished s **Sandy loams** and **Clay loams**. They take ntermediate position between the loam and the two rimary soils, sand and clay, and the table of classiication thus becomes more extended—

Name of Soil.	Percentage of Sand.
Sand, ...	80 to 100
Sandy Loam,	60 to 80
Loam, . . .	40 to 60
Clay Loam,	20 to 40
Clay, ...	— to 20

20. If, in the experiment indicated above, the soil ad contained more sand—say from 60 to 80 per ent. of sand—it would then have been classified as a andy loam. If there had been less sand and more lay—say from 20 to 40 per cent. of sand—then the oil would then have been classified as a clay loam. These groups of soils are based upon the percentage f sand, and the residue in each case represents the roportion of clay. It will be observed that soils re grouped together, having a moderate variation

in composition. There is in fact a range of 20 per cent. for each of these groups. If, for example, a soil contains 10 per cent. of sand and the rest is clay, we should call it a clay soil. If, again, a soil contained 40 per cent. of sand and the remainder is clay, it would be a loam. This is a classification which will be sufficient for our purposes, and may conveniently replace the complicated systems which are supposed to be necessary when treating the subject more in detail.

21. In addition to this physical analysis of the soil we have to consider the several ingredients of which it is composed, and these are determined by **chemical analysis.** Chemistry reveals to us the fact that soils contain a large number of different substances, and that the proportion in which they exist is very variable. It is desirable that these substances should be familiar to the mind, and their general influences clearly understood. They are briefly referred to here without going into those fuller details which may be found in any textbook on chemistry.[1]

22. The soil consists of **two** distinct classes of bodies, viz., those which are mineral or **inorganic** matters, and those which are **organic** substances. When a soil is exposed to the action of fire these two groups are separated, the organic matter is burnt off and dispersed, in a gaseous form, but the inorganic matter remains.

23. The **Inorganic matter** found in soils may be briefly noticed here. **Silica** or silicic acid first claims our attention. This body forms a very large proportion of sandstone, and it exists abundantly in granite and other crystalline rocks. When combined with alkalies or with an alkaline earth, it forms silicates, a series of bodies of the utmost importance in

[1] Johnson's "Catechism of Agricultural Chemistry," by Voelcker, followed by Roscoe's "Lessons in Chemistry," may be named as presenting valuable elementary instruction.

reference to the fertility of the land. Clay is chiefly composed of **silicate of alumina,** that is to say, silica combined with alumina. The fertility of clay, however, is very largely dependent upon the presence of a peculiar form of silicate of alumina, which demands special notice.

24. Some few years since Professor Way carried out an investigation into the character of the silicates of alumina, and disclosed truths of immense importance which have not been generally understood, and consequently have not been taken advantage of. He showed the existence of a class of bodies which are termed **double silicates.** These were silicates of alumina in which part of the alumina had been replaced by an equivalent quantity of some other substance, such as lime, soda, potash or ammonia. Thus we have these double silicates in soils as silicate of alumina and lime, as silicate of alumina and soda, as silicate of alumina and potash, or as silicate of alumina and ammonia. These substances will hereafter be seen to be exceedingly important, and a familiar acquaintance with them is most desirable.

The **Alumina** also possesses in one respect an exceptional character. Whilst it is most valuable in assisting other bodies to enter into the crops growing upon the land, it appears to act rather as an "out-of-door servant," carefully avoiding going into the plant.

25. **Phosphoric acid** is by general consent considered as one of the most important substances found in the soil. Its influence upon the fertility of the land is very great, for every cultivated plant requires a supply for its successful growth. In combination with lime it forms a large portion of the skeletons of animals, and the demand which cultivated plants thus make upon the soil for phosphoric acid enables them more perfectly to supply the requirements of the animals by which these are afterwards used in food. A supply of phosphoric acid in the soil is therefore of very great

importance. It is never found in the soil in large proportion: in our richest soils it barely reaches .5 per cent., that is, in 100 lbs of soil there is rarely as much as ½ lb. of phosphoric acid.

26. We here give a list of the more important bodies usually found in cultivated soils, so that the student may have the opportunity of making himself acquainted with their properties from his textbook on chemistry:

INORGANIC MATTERS IN SOILS.

Silica.	Alumina.
Phosphoric acid.	Lime.
Carbonic acid.	Ammonia.
Sulphuric acid.	Potash.
Chlorine.	Soda.
	Magnesia.
	Oxide of iron.

27. In addition to the inorganic matters of soils we have a second group of substances existing in them as **organic** matter. This matter consists of substances which may have grown under the influence either of vegetable or of animal life, and have consequently been organized as part of some living plant or animal. The process of decay in the soil brings these vegetable or animal remains into such a condition that they again become available for yielding nourishment to vegetation. Any inorganic matter which had formed part of the structure of the vegetable or animal, becomes an addition to the mineral matter of the soil, whilst the organic matter forms a series of substances which practically yield to the soil—

Carbon, with the elements of water (**Oxygen** and **Hydrogen**), in various forms of combination; also

Ammonia and other nitrogenous matters.

28. The inorganic and organic substances in the soil constitute a very large number of bodies, but by the aid of chemical analysis the composition of soils

can be accurately determined. The knowledge we thus obtain enables us to supplement the results obtained by the mechanical analysis (19), and thus we can extend the classification of soils. The mechanical analysis enables us to determine whether a soil is a sand, sandy loam, loam, clay loam, or clay soil; and the chemical analysis enables us to determine whether they are calcareous or peaty. If there should be any large quantity of stone, gravel, or rock, or other exceptional matter mixed with the soil, these would add an additional character; as for example, a calcareous loam with little or much stone, gravel, or rock; or a sand with a large quantity of iron; or a loam with much organic matter, etc., etc. The term **marl** has been proposed for soils which contain from 5 to 20 per cent. of lime, but this is a term which should only be used for describing those beds of earth commonly known as marls.

CHAPTER II.

COMPOSITION OF CULTIVATED CROPS.

29. By the aid of chemistry we are enabled to learn what is the composition of our cultivated crops, and the sources from which plants obtain the materials of which they are made. We find that every plant has two distinct groups of bodies within its structure, and that these may be distinguished as **organic** and **inorganic** matter.

30. If any vegetable matter be carefully burnt, by far the greater portion disappears in the form of smoke, but a portion remains behind in the form of **ash.** This ash consists of mineral matter, and it is known as the **inorganic** matter of plants. It is sometimes described as "the ashes of plants," but in each case the mineral matter of the plant is referred to. When this ash is analysed it is found to consist of a large number of different substances, which are present

in different kinds of plants in very different proportions. One variety of plant is found to contain more of one material than another kind of plant, and the total quantity of ash also varies. Taking the entire range of cultivated crops, we find that, with one exception (24) all the inorganic substances named as present in the soil (26) are taken up by plants and built into their structures. It is also known that plants take up this inorganic or mineral matter with some regularity, selecting only that which they require, and refusing to use that which is not desirable for their growth.

31. That portion of the plant which is burnt off is known as the **organic** matter. In the plant it exists in a great variety of forms, but these have been grouped into two classes—those which contain **nitrogen** are called **nitrogenous** bodies, whilst those which do not contain nitrogen are called **non-nitrogenous** bodies. This is a distinction which must be carefully remembered, for those organic substances are not only distinguished by this difference in their composition, but the presence or absence of nitrogen also **determines the work they can perform.**

32. The following is a list of the principal substances which constitute

THE ORGANIC MATTER OF PLANTS.

Non-nitrogenous Bodies.	**Nitrogenous Bodies.**
Starch.	Albumen.
Gum.	Fibrin (gluten).
Sugar.	Casein (legumin).
Cellulose and woody fibre.	
Oil.	

The **non-nitrogenous** bodies are all composed of the three elements—carbon, hydrogen, and oxygen. Because they contain carbon, they are often called carbonaceous, but it is more convenient to describe them as non-nitrogenous. The bodies named in the **nitrogenous** group contain carbon, hydrogen, and oxygen, but they also contain **nitrogen,** and hence the name which distinguishes them. It may be well at this stage to notice very briefly the several bodies we have thus divided into two classes.

33. **Starch** is a white granular body, very abundant in vegetation, especially in corn and root crops. If you place a little wheat flour in a fine gauze bag, and wash it in a glass, the water quickly assumes a milky appearance. In a short time a white deposit is formed in the glass, and the water has again become bright and clear. The sediment thus obtained is **starch**, which has been separated from the wheat flour. If the bag were now opened, a glutinous mass would be found, in appearance something like soft threads of india rubber. This is the gluten of wheat, to which we shall have to refer subsequently. **Gum** exists in plants generally in a liquid condition, but we occasionally find it thrown out on the surface in a more or less hardened and transparent form, especially in the case of fruit trees, when the bark has been injured. **Sugar** is also found in vegetation in a liquid form. In the well-known sugar-cane, sugar-beet, and sugar-maple, it is found in great abundance, and from all of these sugar is obtained for the public supply. You should, however, remember that it is present in our cultivated plants, even when not in sufficient quantity for it to be separated for use. It has many important duties devolving upon it in promoting the growth of the plant, and its passage through the plant, mingled with the sap, enables it to perform these duties. **Cellulose** is so called because it is the matter of which the cells of plants are constructed, and it is sometimes known as cellular matter. It varies very much in its firmness and strength. When first it is produced in the plant, it is excessively tender and fragile, but as it becomes strengthened by growth so it gradually becomes more rigid and tough, and at length assumes the form of **woody fibre.** These bodies are very similar in composition, and are capable

under certain circumstances of passing from one form to another. It is worthy of note that although the quantity of carbon varies slightly, the weight of oxygen in each is exactly eight times the weight of the hydrogen. **Oil** is found in large quantities in the seeds of some of our cultivated plants—such as linseed, hemp, and cotton seed; in smaller quantities it is found in the grain of wheat, barley, oats, and other varieties of corn.

34. The three **nitrogenous** bodies are exceedingly similar to one another in composition. It has been already stated, that they not only contain carbon, hydrogen, and oxygen, as did the several bodies of the other group; but they also contain **nitrogen,** and because they contain nitrogen, they are called **nitrogenous.** They are also called **albuminoids,** after the name of their leading representative, **albumen.** This substance occurs nearly pure in the white of the egg. It exists also in the juices of plants, especially in corn and "roots." The **gluten** which is separated from the flour of wheat in the manner described (33), is largely composed of **fibrin**, an albuminoid which occurs in blood, from which it is readily separated by gently beating the fresh blood with a few twigs. Little threads or fibres will soon attach themselves to the sticks, and these will consist of the fibrin of the blood. We shall hereafter see that fibrin, or gluten, is an ingredient which largely determines the value of food. **Casein** occurs mixed with fats in the curd of milk; it is also found in peas, beans, &c., in which case it is sometimes called **legumin.**

35. We may now proceed to notice briefly the sources from which plants obtain those substances which we find them to contain. It is not difficult to see that the inorganic matter is obtained from the soil, because there is no other source from which these materials can be obtained. It is also well known that

solid matter cannot enter into a plant so long as it retains its solid form; but it may be received **when it has become a liquid**, by being dissolved in water, or when it has taken **the form of gas.** It may therefore be taken as a rule, that **the inorganic matter** in plants is obtained only **from those portions of the soil which are soluble,** or capable of becoming soluble. There are, however, two bodies—**carbonic acid** and **ammonia**—which are of necessity associated not only with the inorganic bodies, but are also present with the organic group. They are, moreover, to a certain extent exceptional, for plants not only receive these—and **water**—with the soluble matters obtained from the soil, but they also receive them **from the stores existing in the atmosphere.**

CHAPTER III.

FERTILITY OF THE SOIL.

36. In addition to the physical and chemical classification of soils, we have another point of character which is distinctly recognized and determined by the cultivation of the land, viz., the fertility or barrenness of the soil. We can explain by physical and chemical investigations, the causes which influence the productive powers of land, and in many cases these researches indicate the means whereby those powers may be increased or maintained. In the first place, a clear distinction must be drawn between those portions of the soil **which are capable of yielding nourishment** to vegetation, and those which cannot do so. **A soil may contain large supplies** of every ingredient which a crop requires, and may **still be unable to yield them to the plant.** The great truth must be fully realized, that it is

only that portion of the soil which is **capable of being dissolved by rain-water which is available** as food. It is of no practical advantage to a growing plant, that the soil should contain food which will not be ready for use until the next year, or the next century. The life and growth of the plant is determined by the supplies which **are then ready for use,** or coming into use.

37. It has therefore been necessary to distinguish the inorganic matter according to its soluble condition. **Those portions of the soil which are ready for use,** or in other words, can be dissolved in rain-water, are known as the **active** ingredients of the soil; whilst **those which are not ready for use,** because they are not soluble in rain-water, are termed **dormant** or sleeping. The distinction between the two conditions is exceedingly simple; but the influence resulting therefrom is of the greatest importance. An analysis of a soil which represents the total composition of a soil, is of little or no practical value, **unless it distinguishes between that which can be used by the crop, and that which cannot.** The farmer wants to know what ingredients the land contains, which will be of service for the crop he is going to sow, and if an analysis leads him to rely upon all the substances in the soil being ready for his use, he will be deceived. For all practical purposes, a chemical analysis must, in the first place, separate the **dormant** matter of the soil from that which is **active,** and must thus inform the farmer what there is in the soil **which he can make use of.** Without this distinction being drawn, the chemical analysis of soils may be of scientific interest; but it will be calculated to mislead those who fail to distinguish between that which can be used, and that which cannot be used, or, in other words, between **the active and dormant constituents of the soil.**

38. Whilst the active ingredients of the soil are useful for the immediate requirements of vegetation, **the dormant ingredients** have also their duties to fulfil. These constitute **the reserve fund of the soil,** and secure its future fertility. A bad farmer may rob the land of very much of its active matter, and by frequent removal of crops from the land take away its immediate fertility, but he cannot take away that which is in a dormant condition. It is only the good farmer who gets help from this store; and we shall hereafter point out why the one is rewarded by good crops, whilst the other is punished for his bad management. For the present it is enough to remember that the dormant matter of soils is a reserve of fertility for future years.

39. It will be important to know **how this dormant matter becomes useful** for vegetation. **It is changed into the active condition** in the following manner. You have seen that the rain-water containing as it does carbonic acid and oxygen, and also the frost, break down even the hardest rocks, and by their continued action they at length dissolve up much of the finely broken portions of these rocks. Exactly the same result is accomplished in the soil by exposing it to the air, rain, and frost, and by allowing the rain to pass into and through the soil; thus when **the soil** of a field is ploughed up roughly before winter, and **exposed to the air, rain, and frost,** it is not only broken up into fine condition, but the surface of the little fragments of the soil is so acted upon that **some portions become soluble in water**, and ready for being taken into the circulation of a growing plant. These are the natural agencies by which some of the dormant matter is made ready for vegetation by becoming active; there are other means for assisting the same change, but these will be more conveniently noticed hereafter.

40. We have already noticed the fact that plants

draw their inorganic matter and also some of their organic matter from the soil. If this demand on the soil is continued without some return being made to the soil, it is clear that **the land will become exhausted,** and will not be able to supply the requirements of the crops. It will, therefore, not only become exhausted, but as a consequence **will become less productive.** The soil being the only source from which a crop can obtain its inorganic matter, exhaustion arising from any deficiency of this portion of the plants' food is quickly observable. It is desirable that you should realize what crops remove from the land, and this is shown in the following table.

41. **Inorganic Matter** removed from an acre of land, by average crops of the following kinds: (*Playfair.*)

	Wheat.		Beans.		Turnips.		Clover
	25 Bush. Corn.	3000lbs of Straw.	25 Bush. Corn.	2800lbs of Straw.	20 Tons Bulbs.	6Tons Tops.	2 Tons Hay
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs
Potash, . .	7·49	18·21	22·63	89·17	125·73	75·95	52
Soda, ...	·97	·90	6·68	2·69	22·98	16·23	7
Magnesia, . .	3·07	4·11	5·03	11·24	12·27	9·27	35
Lime, ...	·85	9·34	3·63	33·58	37·87	69·81	111
Phosphoric Acid,	11·47	8·15	23·67	12·16	31·11	27·87	20
Sulphuric Acid, .	·08	5·82	·61	1·83	42·26	36·56	13
Silica, ...	·84	101·82	·72	11·84	11·66	2·58	10
Peroxide of Iron,	·20	1·32	·35	—	3·71	2·58	3
Common Salt, .	·03	·33	·90	7·15	28·69	38·15	8
Carbonic Acid, .	—	—	—	—	21·71	21.	—
	25	150	63	168	340	300	259

42. These numbers may be taken as fairly representing **the inorganic matters generally removed** by these crops, but they will **vary according to the weight of the crop, and the character of the soil.** These figures must therefore be looked upon as giving only a general idea of the materials

removed from the land. It would be difficult to remember all these figures, but they represent certain general facts which should be remembered.

43. We see that **different parts of the same plant contain very different** quantities and varities of **inorganic matter:** for instance, the silica in the corn of wheat is about 1 lb. for each acre grown, whilst in the straw there is 100 lbs. and when you examine the straw of wheat you see the bright glassy coating which requires this silica. You also see that beans only require about 12 lbs. of silica per acre, whilst wheat requires 102 lbs., and one lesson this teaches is that **different crops require different kinds of food.** If you notice the requirements of the turnip crop, you will see that an acre of turnips requires about 200 lbs. of potash, and nearly 40 lbs. of soda, whilst a crop of wheat only requires about 26 lbs. of potash, and scarcely 2 lbs. of soda. You must not lose sight of the fact that as different crops require different kinds of food, they therefore **draw from the land different kinds of inorganic matter.** By the removal of our various crops from the land, we remove in them large quantities of those inorganic matters which are necessary for keeping the land fertile, and one of the great objects to be accomplished in successful farming is to be able to do this, and at the same time **make the land more productive** every year. It is, however, quite possible for soils **to be rendered unproductive** by the plant-food they contain being removed, and **the land thereby becoming exhausted.**

44. Some soils are unable to grow crops by reason of their having some injurious matter present, such as some of the lower compounds of iron, salt, and acrid organic matter, all of which prevent healthy vegetable growth.

45. Other soils are unproductive because **their mechanical condition is unfavourable** for vege-

table growth. The roots of plants may be **unable to penetrate a soil** because of its hardness, or the presence of stagnant water may have the same effect. A plant in sending its roots into the soil, requires not only that the roots shall be able to extend through the soil in search of food, but that the soil shall also be in a healthy condition. A supply of water is necessary for the roots, but a supply of air is equally necessary. When the soil is charged with an accumulation of stagnant water, the roots which come within its influence **are unable to discharge their functions** in a healthy manner, and the growth of vegetation is consequently very slow and imperfect.

46. Another condition of fertility is the presence in the soil of **all** the food which the crop requires. An abundance in the supply of one portion of the food does not compensate for a short supply of another equally important portion of the food. Hence the fertility of a soil is determined by the quanity of that essential food which is present **in the least proportion,** and not by that which is in great abundance. To illustrate this by a familiar example, a builder may have plenty of stone for the construction he intends to erect, but if he has little mortar his progress is soon stopped for want of a further supply. It would not assist him if you increased his supply of stone; he wants something else, and until this is ready for his use he can make no progress. It is the short supply of mortar which regulates his work, and not the abundance of stone. It is just the same with vegetable growth; the plant requires a variety of materials, and that essential material which is present in the least abundance regulates the crop, and not those which are more plentifully supplied.

47. The terms **good** and **poor land** have reference to the relative productive powers of land. In a good soil we have a combination of conditions favourable **for the production of large crops**—we have a soil with

a complete supply of food, and it exists in a condition favourable for vegetable growth, and we also have it situated in a climate suitable for the crop to be grown. Such a soil properly cultivated constitutes a good and fertile soil. If either of these conditions is wanting, then it ceases to be good and productive land. You will observe that no one condition is sufficient to make the land productive; the plant-food must be there, and under such circumstances that the plant can use it, the climate must also be favourable for the crops, and the soil must be well cultivated; but the absence of any one of these conditions renders the land unproductive and poor **for that particular crop.**

CHAPTER IV.

FARM MANURES.

48. The more frequent growth of various crops having been found advantageous, the use of manure is now recognized as absolutely necessary for preserving the land in a productive condition. It may be well to see what manures are, and how they accomplish this work. Much of the vegetable produce grown upon the land has to be kept upon the farm, and reduced into such a condition that it can be again added to the soil as manure. If we take a crop of wheat as an example, the corn is separated from the straw, and the corn having been sent to market, the straw is used for stock, and finds its way to the manure heap after it has been so used. Other crops, such as those known as root crops—mangels, turnips, swedes—are consumed by stock on the farm; and the green crops, such as clover, vetches, rape, mustard, &c., are similarly used. These crops are therefore used for a twofold object—first, to produce meat, wool, milk, cheese and similar market-

able products; and, secondly, **to produce manures for the land.**

49. There are two ways in which this vegetable matter is added to the land as manure. When sheep and other stock are fed with it upon the land, the excrement of these animals conveys to the soil those portions of their food which have not been added to their bodies, or used in the support of their warmth. The excrement **returns to the soil** very valuable **inorganic and organic matter** which the plant had **originally drawn from the soil,** and so far as these matters are restored to the land, so far its exhaustion is checked. In the table already given (41) you have seen how largely crops of turnips—which are usually fed on the land—draw upon the soil in their growth; if therefore you return this matter to the soil, from a chemical point of view, you render it almost as capable of producing another growth as it had previously been.

50. In the form of **farm-yard manure** another large portion of this vegetable matter finds its way back to the land. The course of operation is not as simple in this case, for whilst in the former instance the manure became quickly intermingled with the soil, in this case it has to be preserved until it can be carted to the land. In the necessary treatment which this manure has to undergo there is a great **liability to loss.**

51. The production and management of farm-yard manure are based upon certain principles which are easily understood, and with these you will readily become familiar. This manure consists of the straw, or other litter or bedding for the stock, and of the excrements the stock may produce. It is well known that the excrement of the different kinds of stock kept upon a farm varies very considerably. That from horses ferments rapidly and gets very hot, that from cattle is slow to ferment and is consequently a cool

manure, whereas the manure obtained from pigs is intermediate. One of the first things to be secured is **an even distribution** of the different kinds of manure, so that the bulk of manure may have **a similarity of character.** This is most necessary, if any measures are to be adopted for regulating the fermentation; **otherwise one portion is too hot,** and another portion **is not hot enough,** and that treatment which is favourable for one part is injurious for another. **An even distribution** is therefore **the first essential;** this being secured, the fermentation of the heap can be readily controlled.

52. For our present purposes, this fermentation may be familiarly described as a decay or rotting, brought on by the decomposing influence of the nitrogenous matter present, whereby the non-nitrogenous matters present also undergo decomposition. The chief products of this decomposition are **ammonia,** and either **carbonic acid,** or some one or more of **the organic acids,** such as the ulmic acid or humic acid. The ammonia is formed from the nitrogenous matters in the manure, and the non-nitrogenous matters may yield either carbonic acid or the organic acids we have named above, according to the manner in which the decomposition of the manure takes place. If the manure be allowed to get dry and hot, then carbonic acid is formed; but if the manure be kept moist, one of the organic acids is produced. If **carbonic acid** be formed, it combines with **ammonia,** and we have **carbonate of ammonia** formed. This is a very volatile and pungent smelling salt, of which you will have very little doubt after you have once experienced its influence. But if instead of carbonic acid being formed, we get one or more of the organic acids produced, then you have, say, **ulmate of ammonia** or **humate of ammonia** formed, which has a very different character. You have probably seen the **black streams which**

run from manure heaps. These usually contain humate and ulmate of ammonia. This drainage is black and often offensive; but it is not in any way pungent, and the reason of this is, that **the ammonia is not present as carbonate of ammonia.**

53. The successful fermentation of the manure heap is very largely dependent upon the **temperature** at which it is allowed to proceed. The chief condition of success is to avoid loss. If the ammonia formed in the heap be allowed to take the form of a **carbonate of ammonia, and pass away** into the air, the work is a failure by reason of **the most valuable portion** having been **lost.** If on the other hand the fermentation be so controlled that **the ammonia is preserved,** then we may fairly consider **the management a success.**

54. The temperature may be easily regulated by a judicious use of water. **The manure should be kept moist** without being drenched, and the soakage from the manure should be used for this purpose. You may naturally enquire how you are to know when the manure requires more water? If on moving any portion you find any pungent smell of ammonia, be satisfied that it requires to be moistened; or if you find the manure dry, or having a mildewed appearance, you may know that it should have been moistened long before then. A want of care in this respect involves **great losses** every year, for the ammonia lost is our most expensive manure. Many farmers waste it by sending it into the air, and then go to market and buy some more at £100 per ton.

55. You must also understand that there is another way in which this ammonia is lost, and that is, by allowing **too much water** to fall upon it, and wash out the black matter already referred to, and this too often runs into the roads and ditches, and is lost. Farm-yard manure is thus seriously injured, from

want of proper care, until its valuable constituents are either sent into the air or washed into the ditch, and the humorous description of the late C. W. Hoskyns becomes verified in "Drychaff's dung-cart—that creaking hearse—that is carrying to the fields the dead body whose spirit has departed." Very imperfect ideas are entertained of the enormous losses which are thus suffered by men, who would not willingly throw money away, and yet what they waste in their farm-yards they have often to pay for in hardly-earned gold.

56. The extent to which the fermentation of farm-yard manure should be carried depends very much upon the character and condition of the land to which it is going to be applied. If the land should be a sand, or a sandy loam, the manure should be added as short a time as possible before the crop is going to be sown, in order that there may be less time for it to waste away in the soil. These soils, from their want of power to hold a manure—that is, to preserve the manure from this wasting away—cannot be safely trusted to take proper care of it, and therefore it should not be added to the land until you are going to sow a crop which will quickly make use of it. In order that the crop may be able to use the manure quickly, it must be ready for use, or, in other words, the fermentation must have been carried on so far that it has become thoroughly well rotten. The light and free character of these soils does not admit of their being safely rendered more open by the use of long dung which has not been fully fermented.

57. The circumstances are just reversed in the case of clay and clay-loam soils. These possess the power of holding manure in safety, and they are improved in their mechanical conditions by the use of manure which has been but slightly fermented. Upon these soils the fermentation of the manure may be safely permitted to take place after its addition to the land.

58. The rapidity of fermentation is regulated by the admission of air to the heap of manure. If it be desired to make farm-yard manure ferment more quickly, it is turned over so as to lie lightly; but if fermentation has to be checked, it is trodden down into a compact mass. The greater the rapidity of the fermentation may be, the greater is the danger of its throwing off its ammonia into the air, and this renders it the more necessary in such cases to keep it moderately moistened, so that, although it may be a quick fermentation, it may still be kept of a right and proper character. A properly controlled fermentation will preserve the ammonia; but if it be neglected, the most valuable constituent of the manure will be thrown into the air.

CHAPTER V.

ARTIFICIAL MANURES.

59. The term **artificial manure** is one of recent adoption and is confined almost entirely to fertilizers which have been brought into use within the last forty years. Some of these are natural products, as guano and nitrate of soda; others are manufactured, as superphosphate of lime and sulphate of ammonia. This term is not applied to such manures as lime, chalk, marl, and others of ancient use: these may be conveniently termed **natural** manures. Thus beside the farm manures we shall have two classes, viz., the **artificial** and the **natural** manures.

60. The first step towards the introduction of artificial manures was the use of **bones**. These were broken so as to pass through a sieve having a mesh of half an inch. They were and still are known as "half-inch bone." The use of these bones upon dairy pastures had a surprising effect, and they

were therefore used with great profit. It is easy to understand why such good results followed their use. These lands had been used for feeding cows for many generations. Any herbage consumed by these cows would be robbed of its **phosphoric acid,** because the animal required a supply of phosphate of lime for the formation of milk, and for the growth of the young calf, and a very little would be returned to the soil in the excrements. If we examine the composition of milk we find that there is 1 lb. of phosphate of lime in about 25 or 30 gallons of milk, and it may be fairly calculated that the annual demand upon the land for each cow is equal to 80 lbs. of bone. There was, therefore, a deficiency of phosphate of lime consequent upon this long-continued removal from the soil; and when bone was supplied, lands which had become almost valueless, suddenly became rich and luxuriant.

61. The use of bones was also extended to tillage land, and with equally satisfactory results. Large demands are made upon the soil for **phosphoric acid** (41) by its continued removal in corn crops, and by sheep and other live stock, and as these had caused a deficiency upon ploughed lands, like that we have already noticed upon the dairy pastures, similar benefits were gained by the application of bones. The use of bone thus became a settled practice, and was found to be highly remunerative.

62. The next step in the use of bone was its reduction to a fine condition, and it was in that form sold as **bone dust**, for although it was by no means as fine as dust, it received that name. The chief difference was the additional labour of grinding it smaller, so as to pass through a finer sieve, but the effect upon the land was marked by its more rapid action.

63. With a view of attaining still greater rapidity of action bones were frequently "**fermented.**" This was accomplished by putting half-inch bones into a heap,

moistening them with water, and then covering them up with sawdust or fine earth. In a short time these bones became very warm, and when they had been so treated for a few weeks they were found to have become softened, and when used upon the land they quickly broke up and mingled with the soil. Hence they were more quickly ready for supplying phosphate of lime to the plant.

64. It is very desirable that you should be acquainted with the changes that took place in bones so employed, and observe the chemical changes which prepared them for absorption into circulation as plant food. In order that you may fully realize these changes, you must understand that there are at least **three distinct forms of phosphate of lime,** and their composition may be familiarly represented in the following manner—

Composition of Tri-Calcic Phosphate	Composition of Bi-Calcic Phosphate	Composition of Mono-Calcic Phosphate
Phosphoric acid. Lime. Lime. Lime.	Phosphoric acid. Lime. Lime. Water.	Phosphoric acid. Lime. Water. Water.

You will observe the connection between their names and their composition. The **tri-calcic** phosphate, or, as the name signifies, **three-lime** phosphate—has **three equivalents of lime** combined with one equivalent of phosphoric acid. The **bi-calcic** phosphate, or **two-lime** phosphate, has only **two** equivalents of lime with one equivalent of phosphoric acid, and one equivalent of water takes the place of the one equivalent of lime, in which it is deficient. The **mono-calcic** phosphate, or **one-lime** phospate, has only one equivalent of lime combined with one equivalent of phosphoric acid, but it has two equivalents of water to make up the deficiency of lime.

65. You will also carefully note that in each case we have **three equivalents of base** combined with the one equivalent of phosphoric acid. In one case lime is the only base, in the two others they consist of lime and water, but in each case there are three equivalents of base. Hence, phosphate of lime is frequently spoken of as a **tri-basic phosphate,** or a three-base phosphate. I have gone somewhat fully into these details, because **if you clearly understand these terms,** you will be the better able to trace the many important uses which these three phosphates of lime serve in the nutrition of our crops.

66. We are now in a position to follow out our explanation of the changes which take place in bones after they have been applied to the soil. The phosphate of lime present in **bones** is the **tri-calcic phosphate.** When the bones are acted upon in the soil by rain water, which, as you know, contains carbonic acid—or when acted upon by the carbonic acid, produced in the soil—in each case we get one equivalent of the lime removed by the carbonic acid, and the tri-calcic phosphate acted upon then **becomes bi-calcic phosphate and carbonate of lime.** The bi-calcic phosphate dissolves gradually in water, and is thus taken up into the circulation of plants in a soluble form. The changes in the size and condition of the bones which have been mentioned as being adopted (60, 62, 63) all helped in various degrees to promote their decomposition. The action of the carbonic acid and water was greater when the bones were broken into small pieces, because a larger surface was thus exposed to their influence. The fermented bones were quickly acted upon in the soil, because by this fermentation they had been made soft, and consequently they soon broke up in the soil.

The carbonic acid of the atmosphere carried into the soil in the rain-water, and any which might have been produced in the soil, helped to make the bone more rapidly soluble. The following diagram shows the action of the carbonic acid upon the tri-calcic phosphate in bone—

Composition of Tri-Calcic Phosphate.	Re-agent Employed.	Products of Decomposition.
Phosphoric acid. Lime. Lime. }	Water.	Bi-calcic phosphate.
Lime.	Carbonic acid.	Carbonate of lime.

67. Up to 1840 phosphate of lime was added to the soil by the use of bones, having varying degrees of fineness; but, in that year, Liebig proposed **a chemical treatment of bones,** whereby they were rendered more rapidly soluble, and consequently were ready for use for the crop with less loss of time. In fact, instead of the farmer having to wait some months for any general action of the bone, this chemical treatment made the bone ready for immediate use. Liebig's discovery of the means whereby these results could be attained with such promptitude, was—like many other great discoveries—exceedingly simple. He imitated the natural decomposition of bone as it takes place in the soil, but he accomplished the work more quickly by using a stronger acid. We have seen (66) that the carbonic acid **slowly and quietly** took from the tri-calcic phosphate some of its lime, and thus increased the solubility of the bone, but Liebig used sulphuric acid, which is a very powerful acid, and this accomplished in one hour more than the carbonic acid could do in one year. The chemical change was practically **completed at once,** and the phosphate of lime in the bone became **immediately** soluble in **water.**

68. But Liebig's process did something more than gain time—he obtained the tri-calcic phosphate of the bone in a thoroughly soluble condition, and in this respect **the chemical change he accomplished went beyond that which naturally occurred** in the soil. The difference will be more clearly understood by reference to the following diagram:—

Composition of Tri-calcic Phosphate.	Re-agent Employed.	Products of Decomposition.
Phosphoric acid. } Lime. }	Water. } Water. }	Mono-calcic phosphate.
Lime. } Lime. }	Sulphuric acid.	Sulphate of lime.

69. If you compare this diagram with that immediately preceding it, you will see that **a different form of phosphate of lime is obtained** from that which had been produced in the soil **by the slow decomposition** of the bone. In the former case a bi-calcic phosphate was produced, and this is a **slowly soluble** phosphate of lime. In the latter case we have mono-calcic phosphate produced, and this is **rapidly soluble** in water.

70. The treatment of bone by means of sulphuric acid thus introduced by Liebig therefore produced a new kind of manure, which has been distinguished as **super-phosphate of lime.** You will readily understand that it was called **super**-phosphate of lime, because the phosphoric acid which had been combined with three equivalents of lime **had been concentrated** upon one equivalent of lime, and the lime was thus **super-phosphated,** or, in other words, the lime was **over-charged** with phosphoric acid. It must be remembered that not only is mono-calcic phosphate thus formed, but a large quantity of sulphate of lime is also produced by the action of the sulphuric acid on the bone, and consequently the

"super-phosphate of lime" is really a mixture, of which the active ingredient—mono-calcic phosphate—forms sometimes not more than one-fourth of the entire weight.

71. This discovery of Liebig's led to the establishment of an entirely new branch of chemical manufacture, for although for a time farmers manufactured their own super-phosphate, by purchasing bones and suphuric acid, it was soon found that a manufacturer, with convenient machinery, could do the work far more advantageously and economically. The late Mr. Thomas Proctor of Bristol was the first manufacturer of super-phosphate of lime. He was present at the meeting of the British Association when Liebig announced his great discovery. As soon as it was made known he travelled to Bristol with all speed, and at once commenced the manufacture, promptly sending out Liebig's new manure ready for use. The economy of the new process was soon recognized, and the manufacture of artificial manures advanced with incredible rapidity.

72. The next advance was the discovery of Mr. J. B. Lawes, in 1842, whereby he proved that **mineral phosphates of lime** were capable of being manufactured so as to produce the same mono-calcic phosphate, which had previously been manufactured **solely from bone.** This led to an extensive search for rocks, and other mineral deposits containing the tri-calcic phosphates, and the result has been a considerable decrease in the cost of the materials used in the manufacture, which has resulted in **a cheaper supply** for the farmer's use. The new description of super-phosphate of lime thus introduced was distinguished as **mineral super-phosphate,** that is to say, super-phosphate of lime manufactured from mineral phosphates. Subsequent experience has confirmed Mr. Lawes' original opinion, and has resulted in super-phosphate of lime being now very largely made by the judicious use of mixtures of

mineral phosphates and bone, whereby economy of manufacture has been coupled with high quality.

73. Another source of phosphate must also be noticed, and that is known as **bone ash**. This has been largely imported from South America, and is the ash of the bones, used for fuel to melt the tallow obtained from the herds of cattle slaughtered for their tallow, hides, and horns. Many thousand head of cattle were thus slaughtered, and as fuel was scarce, the bones were so employed. For many years the ash was not of any value, and immense quantities had been accumulated, when the bone ash suddenly became of great value by reason of its new use for the manufacture of super-phosphate of lime. Bone ash has since then been found valuable for many other manufactures.

74. It has been explained (66) that bi-calcic phosphate is produced in the soil by the gradual decomposition of bones, and it may be added that the growth of vegetation arising from this use of bones is always **of a most healthy character.** Liebig's important discovery, which was intended to obtain the same results more rapidly, has been made use of very extensively, but it has been recognized that we have to a great extent "over-manufactured" our phosphate by converting it entirely into a mono-calcic phosphate. This more rapid process has not, however, accomplished **the same result**, and the unhealthy character of vegetation often testifies to this fact.

75. There is every reason to believe that the mono-calcic phosphate, by reason of its solubility, is easily distributed through the soil, but that it is too acid in its character to enter into the circulation of plants. If a manure containing mono-calcic phosphate be added to a calcareous soil, the lime with which it comes in contact combines with it, and the mono-calcic phosphate becomes changed into a bi-calcic

phosphate, which gradually enters into the circulation of the plant. The presence of lime in a soil, even in a small proportion, accomplishes this result, and by reason of the less soluble condition to which it is thus reduced, there is also less danger of the phosphate being washed out of the soil. On many light sandy soils the use of ordinary super-phosphate is attended with great loss, as the mono-calcic phosphate is washed out of the soil, by the rain passing through it. In these cases the use of bone is still found the most economical form for adding phosphate of lime to the soil, as this waste is thereby prevented.

76. It is, however, quite possible for the form of phosphate produced by the action of sulphuric acid on bone or other phosphates to be of the same character as that produced by the decomposition of bones in the soil. By the use of one-half of the sulphuric acid required to make mono-calcic phosphate, we obtain the same form of phosphate of lime as is produced in the soil when bones decompose in the ordinary manner. It is, as we have seen, **a more desirable form** of phosphate, so far as the healthy growth of vegetation is concerned, and it is by no means, improbable, and much to be desired, that circumstances may shortly lead to its more extensive use.

77. One other subject, closely associated with super-phosphate, demands notice in passing, viz., the "**reduced phosphates.**" When a manufacturer has made a large quantity of super-phosphate, and has ascertained its strength by analysis, it very frequently happens that after a lapse of two or three months the super-phosphate is found to be reduced in strength It is then known as a **reduced super-phosphate.** A super-phosphate having 25 per cent. of soluble phosphate is often found to be reduced to 22 or perhaps to 20 per cent. If the value of this super-phosphate were to be determined by analysis, the manufacturer would lose largely, because chemists

base their estimates of the value of super-phosphates upon the quantity of soluble phosphate which they contain. As a matter of fact, manufacturers and many farmers know that the reduced super-phosphates, instead of being of **less** value, are really of **greater** value for the land, and will be found more valuable fertilizers than before the reduction took place. This appears a somewhat contradictory statement until the cause of reduction is known. The simple fact is that the mono-calcic phosphate which was present in the super-phosphate in the first instance, is diminished in quantity by a portion being changed into the form of bi-calcic phosphate, and this portion which has become so changed is no longer estimated by analysis as a soluble phosphate. All that has been so changed in character represents so much loss to the manufacturer, if he sells simply on the basis of the soluble or mono-calcic phosphate present. At the same time it means an actual increase in the value of the manure, for those farmers who use these "reduced super-phosphates" find that they are generally **most lasting** in their action and altogether **more valuable manures.**

78. This "reduction of super-phosphates" may be, and is produced artificially, by an admixture of finely-pulverized bone. Some of the highly-soluble phosphate is thus reduced to the slowly-soluble form, and yet the fertilizing power of the manure is increased. Here, as in the case of the reduced super-phosphates already referred to, there would be a serious loss to the manufacturer, if the value were determined by the present system, and accordingly this very useful practice is discouraged.

79. In the purchase of super-phosphate of lime it is usual for the strength to be described by saying that it contains a certain percentage of **soluble phosphate.** As this is a term commonly used in every market town in the country, you should clearly under-

stand what is meant by it. Soluble phosphate is only another name for mono-calcic phosphate, which has been already described as being rapidly soluble in water. If a portion of super-phosphate of lime be added to a proper quantity of water, and especially if tepid water be employed, in a few hours the whole of the mono-calcic phosphate is dissolved out of it. Thus the soluble phosphate is separated from the rest of the manure, and its quantity is estimated by chemical analysis.

80. Purchases are frequently based upon the strength of the super-phosphate, which is often sold as containing, say 25 per cent of soluble phosphate. It would of course be a perfectly reasonable contract that a super-phosphate of lime should contain say 25 per cent. of soluble or mono-calcic phosphate, but in the great majority of cases something different from this is really intended. The strength intended is more correctly stated when expressed as equal to 25 per cent. of **tri-calcic phosphate rendered soluble.** You may take it that 20 cwt. of tri-calcic phosphate rendered soluble will only yield about 15 cwt. of soluble or mono-calcic phosphate, so that 25 per cent. in the trade sense, viz., 25 per cent. of tri-calcic phosphate rendered soluble, really means only 19 per cent. of soluble or mono-calcic phosphate in the sample.

81. It may be convenient to notice at this stage the practice of selling manures upon the "**unit system,**" which is becoming more and more general, viz., a sale of super-phosphate at an agreed price per unit. When a super-phosphate is thus sold which contains 25 per cent. of tri-calcic phosphate made soluble, this represents 25 **units** at the agreed price, it may be 3s., 4s., or more **per unit, per ton.** If it contains 30 per cent. this would represent 30 **units,** and thus the number of units always corresponds with the amount per cent. A super-phosphate containing 25 units and sold at 4s. per unit would produce £5 per

ton; or if it contained 30 units at the same price per unit, it would be £6 per ton, and so on. It is on this basis that the **valuation of manures** has been established. Experience, however, has shown that great care is necessary in making these valuations. One difficulty exists in fixing the price per unit, but this is necessarily subject to the variations of the market, and is a fair matter for contract as between buyer and seller.

82. It will be easily understood from what has been said that the method of valuation indicated above (77) is somewhat defective, for whilst the bi-calcic phosphate is a most useful part of the manure, the valuer pays attention almost entirely to the mono-calcic phosphate, because the estimation of the former is somewhat difficult, and its value has not yet been fully appreciated by chemists. This is a matter of considerable importance; for so long as the present system of valuation is maintained, so long manufacturers will be compelled to sell, and farmers to buy, **over-manufactured manures**, having a higher degree of solubility than is consistent with the healthy growth of our crops. On the other hand, the production of a form of phosphate whose high value is well known to the farmer and the manufacturer, is now rendered practically impossible. The magnitude of this question will be more fully realized when you consider that the sales of super-phosphate represent an annual outlay of between two and three million pounds sterling.

83. There is another class of artificial manures which are chiefly distinguished by the presence of **nitrogenous** compounds. **Peruvian guano** is one of the richest manures of this class. Its value depends not only upon the large quantity of ammonia which it contains, but upon the fact that it is mixed with various other valuable fertilizers. Guano is the dung of sea-birds, which has accumulated for many centuries in a climate where there is but little rain to

injure it. It was first imported into England in 1839, and at that time the supply in Peru was very large, some of the beds being fully 200 feet in depth. Many millions of tons have been imported since that time, and the quality is not so good now as it used to be. An average of fifty cargoes, imported into England before 1855, contained nitrogenous matter equal to rather more than 17 per cent. of ammonia. At the present time, it may be taken as containing nitrogenous matter equal to about 8 or 10 per cent. of ammonia. Peruvian guano also contains a large quantity of phosphates in an exceedingly valuable form, and these add to its value.

84. In 1864, Dr. Voelcker recommended the treatment of Peruvian guano by the use of a small percentage of sulphuric acid, with the twofold object of rendering the ammonia it contained non-volatile, and of making the phosphates more quickly soluble in water. The first was accomplished by the sulphuric acid combining with the ammonia, and forming sulphate of ammonia. The second change arose from the phosphate being converted into mono-calcic phosphate in the manner already described (68). This treatment of Peruvian guano was commenced on the continent in 1864, by Messrs. Ohlendorff, and has since then been very largely carried on in England—the manufactured article being sold as "Dissolved Guano."

85. **Sulphate of ammonia** is another nitrogenous manure which is very largely used in this country, and which exerts as great an influence as a fertilizer as the Peruvian guano, if not greater. This is prepared from what was once known as the waste liquor of gas works. It is a waste liquor no longer, as it is carefully sought after for the production of sulphate of ammonia. This manure is a white crystalline substance, more or less discoloured by impurities, and is obtained by first adding sulphuric acid to the gas

liquor in sufficient quantities to combine with the ammonia, after which the sulphate of ammonia is crystallized in the usual manner. The chief bulk is employed by the manufacturers of artificial manures, who fully understand its value, and use it in proper combination with other fertilizers. Its value depends upon the percentage of ammonia which it contains.

86. **Nitrate of soda** is an exceeding popular manure of the same class. It is a nitrogenous manure; but it does not contain ammonia like the two preceding manures. Here the nitrogen is present as nitric acid, and this is combined with soda. It is a very powerful manure, of a white crystalline appearance. It is largely imported from Peru and Chili, where it exists as a crust near the surface of the land. This is therefore a second and very important manure which we receive from Peru. Nitrate of soda is largely used for manufacturing purposes, besides being employed for making artificial manures. Farmers have the advantage of being able to supply their requirements by the use of other nitrogenous materials, when the supply of nitrate of soda is scarce. For other manufacturing purposes, nitrate of soda is actually necessary. The demand for these uses therefore takes the precedence by the supply being secured, even at an advanced price. Its agricultural value is usually determined by calculating the nitrogen it contains, as equal in value to the same quantity of nitrogen in the form of ammonia; that is to say, the nitrogen, whether in the form of a nitrate, or in the form of ammonia, is usually taken as of the same market value.

87. Another source of nitrogen for fertilizing purposes is the employment of **woollen waste, shoddy,** also **dried flesh** and **blood, fish refuse, rape dust, seaweed,** &c. These all contain a large percentage of nitrogen, which by decomposition can be converted into ammonia. They render convenient supplies of ammonia to the

plant through its several successive stages of growth by the slow and **gradual formation of the ammonia**. We have referred to the fact (56) that many soils have little power for retaining ammonia when it is added in a soluble form, and from these soils much is lost by using ammonia in such a form, for instance, as the sulphate of ammonia; whereas, by selecting fertilizing substances which will supply ammonia slowly by their gradual decomposition, the growing crop has a better opportunity for using it without waste.

88. **Potash** exercises an important influence in promoting the fertility of the land. The nitrate of potash, which is a most powerful manure, always commands a price considerably higher than nitrate of soda, because the former is used for the manufacture of gunpowder, whereas the latter cannot be so employed. Some other source of potash had therefore to be found (107). The ashes of wood fires yielded small supplies, and their influence upon the land was generally very marked, but the quantity obtained in this way was very small for the purposes of manuring land. Some few years since large deposits of potash salts were discovered in Germany, and they were introduced into this country under the name of **kainite.** It generally contains about 25 per cent. of sulphate of potash. In some cases the use of potash in this form has been productive of most satisfactory results, but as a rule its use has not realized the sanguine expectations which were so generally entertained. This in no way depreciates the value previously set upon a proper supply of potash; it rather indicates that we have in some degree failed to employ the kainite so as to secure the best results which the potash it contains is capable of producing.

89. **Common salt** is also largely employed as a manure. It is a compound of chlorine and sodium, and by its use we are enabled to supply to the soil a

much-needed fertilizer—soda. The chief source of supply is from salt-mines, such as exist so largely in Cheshire, and also from the evaporation of sea-water. Good samples of Cheshire salt contain as much as 98 per cent. of chloride of sodium; but the salt obtained from sea-water usually contains chloride of magnesium, and it is more than usually disposed to become moist, which renders its distribution more difficult. Its action as a fertilizer is in many respects peculiar, by reason of its apparently inconsistent influences, for in many cases we see it giving a decided check to vegetable growth, and yet thereby increasing the production of corn. For some crops, such as the mangel wurzel, salt is a direct requirement of the plant as food. Beans, cabbages, and onions also appear to flourish with liberal supplies. The analysis of the ash of mangel wurzel shows considerable variation in the quantity of salt present. According to Way and Ogston the average of four analyses of the bulb showed a variation of from 10 per cent. to 49·51 per cent. of salt in the ash, and an average of 24·55 per cent. The tops of the mangel wurzel, on the same authority, contained 33·96 per cent. of salt in the ash. It is therefore evident that this crop in particular requires a supply of salt as plant-food. It is present in the ash of every cultivated plant, and it must therefore be regarded as generally desirable as a food for these crops. The necessity for supplying it to the land will be determined in a great measure by the supply already existing in the soil. Lands which are situated near the sea have a supply carried by winds from the sea, and the quantity of salt which is thus carried inland for twenty, thirty, or sometimes even forty miles, will surprise those who have never tested this supply.

90. One important influence which salt exerts on vegetation arises from its power **to check plant growth,** possibly arising from the action of the

chlorine which it contains. Whatever may be the direct cause, it is evident that we have in salt an agency which can be used to check the growth, even up to the extent of destroying the life of the plant. This is a most important agency, and when more fully understood will be more generally utilized. In the processes of cultivation, the necessity for this influence often arises. Take, for instance, our corn crops. If the land be too highly manured, these crops have a tendency to produce straw rather than corn, the grassy character of the plant being thus unduly encouraged. This growth of the straw is often too rapid to allow of the plant bringing up the necessary supplies of mineral matter, for securing a strong straw. The first disadvantage is seen in a large growth of weak straw, which has not sufficient strength to stand whilst the seed is being formed. If this difficulty should be surmounted, then this tendency to continue the growth of straw, often prevents the formation of a good ear of corn. Every farmer knows the dangers resulting from an overgrowth of straw; but whilst avoiding this danger, it is generally desirable for him to have his land in such high condition that he may be safe for a good crop of corn. He has therefore to adopt such a medium course, as local experience indicates to be most likely to secure a good produce of corn, without an overgrowth of straw. An unusually wet season, however, frequently upsets the best calculations, the crop suffers, and yields an inferior quality of corn. Salt is frequently found valuable in such cases, by the check it gives to the growth of straw, and the greater strength gained by the straw in consequence of this impeded growth. It may therefore be generally considered as shortening and strengthening the growth of the straw.

91. In like manner, when nitrate of soda has been freely used upon growing corn, there is an energetic growth of the straw, which continues during the for-

mation of the corn, so much so in some cases as to give the ear the appearance of having been over-stretched, the spaces between the several grains of corn being larger than usual. When this happens, the production of a good crop of corn is extremely improbable. In such a case as this, the influence of salt would have been most valuable, as it would have checked the excessive growth of straw, and thereby encouraged the growth of corn. It does not prevent the nitrate of soda exerting its full fertilizing power, but it appears to exercise a controlling influence, whereby that power is more satisfactorily utilized. There are, however, exceptional soils, on which there is not the slightest fear of producing too much straw by any ordinary use of manure; to these cases we are not making reference. Our remarks illustrate the action of salt in those cases where the character of the soil, or the employment of a stimulating nitrogenous manure, favour high cultivation, whilst the salt, acting as a "brake to the carriage wheels," renders a quick pace much more safe.

92. The tendency which salt exhibits **to attract moisture** from the atmosphere in some degree influences its employment upon light lands, but for this purpose a salt known as **"hide salt"** is specially valuable. Foreign hides are often salted for shipment to this country, and the salt so used is sold as manure when the vessels are discharged. This salt has by this employment become impregnated with animal matter, which adds to its value as manure.

93. **Special Manures.** These are a class of manures specially prepared for various crops. Each manufacturer supplies that fertilizing matter which he considers best for any particular crop, and he supplies it in that form, and in that association, which his experience leads him to consider to be most likely to produce the best crop. These are generally sold without guarantee as to strength, or percentage of

solubility, and give the manufacturer free scope for the exercise of his judgment. As a rule, very great excellence has been attained by the careful researches carried out by the manufacturers, and by the purchase of the best materials at the lowest prices. Their opportunities for watching the results of their several trial manures are unusually good, and it is to their interest to observe these results, and carefully note instances of success and failure. It is just as they succeed in manufacturing a successful manure, that their public reputation will stand or fall on the market. It must be admitted that they have done much; but, on the other hand, if farmers had a fuller knowledge of what they were using, they also would be observers, and would soon point out which of the several constituents could be lessened, and which could be advantageously increased, so as to suit their own farms, or certain recognized portions thereof. The manufacturer, to secure a general success, has to provide for **all** the requirements likely to arise, and thus provision is unavoidably made for many requirements which do not arise. The farmer has thus to pay for some unnecessary supplies, whereas, just in proportion as he knows what he is using, and watches the influence of variations made by way of experiment, so he ultimately gets to know what his farm requires, and thereby he avoids purchasing that which is not necessary.

It is by carrying out **experimental trials** in different neighborhoods that this information will be best obtained, and in this way variations in soil and climate may be most judiciously and economically dealt with.

CHAPTER VI.

NATURAL MANURES.

94. **Lime** ranks as one of the most important manures at the farmer's command, and its use dates from very early periods of time. It exists very abundantly in many of our rocks, as in our limestone and chalk formations, in the form of carbonate of lime, which is a compound of carbonic acid and lime. It is also found in rocks as sulphate of lime, or gypsum, which is a compound of sulphuric acid and lime. In this form it is far less abundant than as carbonate of lime. There is another supply of lime found in combination with phosphoric acid as phosphate of lime, but this exists in a still more limited quantity. This is however a very valuable manure, and is carefully sought for wherever it can be easily raised and conveyed to a port for shipment. In the West Indies, Spain, Portugal, Germany, Carolina, &c., very large quantities are raised, and sent to England for the manufacture of manures. Considerable quantities are obtained in England, in the form of coprolites; but the present supplies are inferior in character to those at first raised, and they scarcely compete with the foreign supplies of high-quality phosphate of lime, which are now so largely used.

95. The use of **lime** as a manure is practically limited to the employment of various forms of carbonate of lime, either in a natural or prepared condition. It is true that in combination with sulphuric acid and phosphoric acid it is added to the soil, but the sulphate of lime and the phosphate of lime so employed are used for the sulphuric and phosphoric acid they contain, rather than for their lime. The carbonate of lime must be regarded as the source of the lime used for the purpose of manure.

96. The action of lime as a manure is entirely regulated by the form and manner in which it is employed. It is very desirable for these variations in practice to be distinctly understood. The form in which lime is most largely employed is as **burnt lime.** In its preparation, limestone or chalk rock is placed in a kiln, with some fuel, and after an exposure to the fire thereby produced, we find the "lime" has changed its character and its composition. The carbonic acid which was present has been driven off, it is therefore no longer a carbonate of lime, but lime. It is sometimes called **quick lime** sometimes burnt or calcined lime, or **caustic lime,** but you must remember that it is no longer a carbonate of lime, because the carbonic acid has been driven off.

97. The burnt lime is very different from the limestone or chalk rock, as you will readily see if you take a lump of each, and put some water upon them. The limestone and chalk are not changed by the water, but with the burnt lime it is very different. A violent action takes place, which produces much heat, and breaks the burnt lime into a fine powder. This is commonly known as "**slaking the lime,**" but viewed from a chemical point of view, the change which has taken place is a combination of the water with the lime. It is not simply a mixture of the water with the burnt lime, which would only have the effect of wetting the lime, but a definite union has taken place between the water and the lime, and a new product is obtained, viz., **hydrate of lime,** or, as it is more commonly known, **slaked lime.**

98. If this slaked lime is allowed to remain exposed to the air, the carbonic acid of the atmosphere readily enters into combination with it, and we have carbonate of lime again produced. Carbonic acid, which we drove away by burning in the kiln, again associates itself with the lime, and the practical change which has taken place is the reduction of the carbonate of

lime from its original rocky condition into a fine powder. By this reunion of the carbonic acid with the lime it has now lost its caustic character, it has ceased to be a caustic lime, it has again become carbonate of lime. You will find that if you clearly understand these simple changes in the character of lime, that you will easily distinguish the special advantages which are to be gained by the use of burnt or caustic lime upon the land.

99. The **organic** matter in a soil is **rapidly acted upon by burnt lime.** We have already noticed that the slaked lime quickly draws the carbonic acid of the atmosphere into combination with itself, and the same action takes place in the soil; for when the organic matter undergoes decomposition, carbonic acid, or some form of organic acid, is produced and is immediately seized by the lime. This action favours the more perfect decomposition of that organic matter which remains, and as rapidly as the presence of air or moisture permits, fresh food is provided for the lime to lay hold of. The harsh and hungry character of the lime which we called its caustic character soon becomes satisfied by the carbonic acid or other organic acid, and it forms a mild and gentle ingredient of the soil, in the form of a carbonate or other salt of lime.

100. In some soils we find a large quantity of these organic acids, existing in them to the great injury of the land, and these soils are well known as being "**sour.**" A farmer who has no knowledge of chemistry will tell, quite as accurately as a chemist, when a land is sour, for he judges by the character of the herbage growing on the surface. This herbage is always harsh, and of little value as food. When the mower cuts it with his scythe, he soon finds the cutting hard and difficult, for his scythe quickly loses its sharp edge, and he tells his master that the land is sour and wants lime. The beneficial action of lime

in such a case as this, you will readily understand, arises from the lime combining with these organic acids, which make the land sour, and turning them into a condition in which they are, to say the least, harmless; for the acid or sour bodies present have been neutralized.

101. This removal of the sourness of land is sometimes described as a **sweetening of the herbage.** The two terms practically represent the same change, for when by the use of lime this sourness of the land has been corrected, we find a sweeter and **better quality of herbage** produced, and the stock in the field prefer it.

102. In such cases as this the burnt lime acts very quickly upon the organic acids in the soil, and in performing its work it shows great energy of action. This has led to its being called **quick-lime,** in distinction from the **dead** and inactive forms which lime assumes after its work has been performed. You should, however, remember that burnt or calcined lime, caustic lime, and quick-lime, are all different names for the form of lime which is drawn fresh from the lime kiln.

103. Burnt lime also acts upon the **inorganic** matter of the soil, and in many cases it liberates potash and soda from the **dormant** matter of the soil, and renders them **available** for vegetable growth.

104. Its most important action on this portion of the soil is probably in the assistance which it renders for the formation of the **double silicates of alumina.** These we have already noticed (24) as having a very important influence upon the fertility of the land. It has been stated that there are four of these double silicates of alumina which have been described as silicates of alumina in which part of the alumina is replaced by lime, soda, potash, or ammonia. You are probably aware that ammonia is more valuable than potash, whilst potash is of more value than lime, and lime is of more value than soda. The silicate of alumina

appears to exercise a similar order of preference. If a double silicate of alumina and soda exists in the soil, and lime should be brought in contact with it, the silicate of alumina gives up the soda and takes up the lime instead, and thus we get silicate of alumina and lime. The presence of soda will not enable it to displace the lime, as the silicate of alumina prefers the lime to the soda. If, however, some potash be added, the lime is given up and the potash is taken into combination, because the silicate of alumina prefers the potash, and thus we obtain silicate of alumina and potash. But if ammonia comes within the influence of this compound, there is so much preference for the ammonia, that even the potash loses its position, and then we get silicate of alumina and ammonia formed.

105. The chief difficulty, as far as we know, appears to be in getting the silicate of alumina to **commence** taking in one of these substances. If by any means you can produce even the lowest form, viz., the double silicate of alumina and soda, there is no difficulty in advancing through the higher stages. The real difficulty is in the commencement of the series. In this respect the energy of the caustic lime appears to be very valuable, and thereby the double silicate of alumina and lime is probably produced. The special action that caustic lime, which has been slaked with water containing salt, has upon silicate of alumina, favours this view. We may, therefore, regard the action of caustic lime upon clay—which latter substance, you will remember, consists very largely of silicate of alumina, as contributing to the production of that most valuable class of bodies which have been called the double silicates.

106. Caustic lime also favors **the production of nitrate of potash** in the soil. This action, when it takes place in the compost heaps of the farm, admits of more careful observation than when the change is accomplished in the soil. There is, however, no reason

to doubt, but that similar changes take place in the soil under like conditions. In properly constructed compost heaps, especially where some farm-yard manure is present, we have, in fact, a very near approach to what are known as nitre-beds—or beds of earth constructed for the production of nitre.

107. Nitre (or nitrate of potash) is largely used for the manufacture of gunpowder. It happened that in the wars between England and France, in the last century, the British cruisers kept such a sharp look-out for the trading vessels going to France, that there was often a very great difficulty in getting the nitre they required for their supplies of gunpowder. In 1775, the French government offered a prize for the best method of producing saltpetre or nitrate of potash in that country. The prize was awarded in 1776 to Mons. Thouvenel, and from that time nitrate of potash has been largely manufactured by what are sometimes known as saltpetre plantations, and in other places as nitre-beds. The general formation of these is very similar. Earth is either intermixed with decaying vegetable and animal matters, or else it is charged with the manure from sheep, and two necessary conditions are thus secured, viz., nitrogenous matter and earth. After a short time chalk or marl is intermixed, and the decomposition which takes place leads to the formation of nitrate of potash. When it is desired to separate the saltpetre, it is washed out by water, and the solution is evaporated. Care is taken to protect the nitre beds from rain, which would wash away the nitrate of potash, and the earth is laid up in small heaps so as to secure the full influence of the atmospheric air. In some cases the lime is used in a caustic form, and by its intermixture with the soil much of the potash of the soil is liberated, before the caustic lime is converted into the form of carbonate. Soil which has been thus prepared and intermixed with any decaying vegetable or animal matter is admirably adapted for the production of

nitrate of potash, and the quantity is largely increased by small additions of liquid manure. These conditions are very commonly fulfilled in the soil, and we may therefore fairly consider that lime acting upon the farm-yard manure, and the inorganic matter of the soil promotes the production of nitrate of potash.

108. We have already noticed the necessity which exists for a supply of **lime** to meet the requirements of the crops so far as regards that quantity which the plant receives **as food.** **Every cultivated plant** needs a supply of lime for the proper building up of its structure, but some, like the beans and peas, clover and root crops, require it in greater abundance than other crops.

109. The **physical or mechanical action of lime** upon heavy clay soils is another feature of its character which must not be overlooked. It makes these soils more mellow, and therefore more easily cultivated, at the same time it favours the admission of air and water into the soil, with all their powers for developing its fertility, and it gives a more healthy character to the vegetation growing upon such land.

110. The advantages arising from the use of caustic or quick-lime may be enumerated as follows:—

(1) It encourages the decomposition of the organic matter in the soil.

(2) It neutralizes the organic acids which make land sour, and it improves the quality of the herbage.

(3) It assists the liberation of alkaline matters (potash and soda) from the dormant ingredients in the soil.

(4) It promotes the formation of the double silicates.

(5) It favours the production of nitrate of potash.

(6) It contributes food essential for the perfect growth of the crops.

(7) It improves the physical character of the soil, and promotes healthy growth.

These are exceedingly important duties for any manure to be capable of performing. We may now proceed to notice how the caustic lime can be most economically and advantageously enabled to perform these duties.

111. It has been already explained that some of these duties can only be accomplished by lime when caustic. In such cases the lime should be brought into work with the least possible loss of its causticity. You are already aware of the fact that the carbonic acid of the atmosphere has a strong disposition to combine with the caustic lime, and in doing so the lime loses its caustic character and becomes a carbonate of lime. As a rule, much of the lime used as manure is allowed to be exposed to the weather to a very great extent before it is able to commence its work.

112. There are two methods by which caustic lime is slaked. One of these is a **bad** and **wasteful** system and the other is a **good** and **economical** plan. It is a too common practice for lime which has been drawn for manure, to be distributed over the land in small heaps, and left there until the rain has slaked it. This not only leads to much delay, but, as the slaking takes place gradually, much of the lime has been acted upon by the carbonic acid of the atmosphere, and much of its power lost before it is brought into use. Compare with this the care taken by a mason when slaking lime for mortar: no delay is allowed, it is done quickly by adding sufficient water, and then it is heaped up and covered from the air by sand. Some farmers adopt the same plan, and as soon as the heaps are made in the field, a water cart carries round the water required for the proper slaking of the lime, and it is then heaped up, and protected from the air by a covering of earth. For building purposes it is necessary to slake the lime thoroughly and without loss, and it is equally so for use as a manure. The only difference is that the loss is more easily detected

in the case of the builder, but it is equally a loss to the farmer whether he knows it or not. Lime is, after all, an expensive manure before it is got upon the land, and it is unwise to allow it to waste.

113. A proper system having been adopted for slaking the lime, it should not be opened to the air until it is going to be spread over the land. When it has been spread, it should be **at once harrowed into the soil**, thus bringing it so into contact with the soil, that it will exert its powers upon it, rather than allow the quiet influence of the carbonic acid of the atmosphere to rob the lime of its energy.

114. Another reason for adopting the use of the harrow for covering in the lime, instead of using the plough, is the well known **tendency of lime to sink in the soil.** If it be mixed with the soil near the surface, the ordinary tillage operations have a tendency to keep it there; whereas, if the lime were ploughed in, it would thereby commence its work at a low level, and under many disadvantages.

115. Another point demands consideration in connection with the use of lime, viz., whether the use of lime **renders a supply of some other manure necessary.** Many of the old maxims held by farmers of experience, are found to have a foundation of truth; but none more so than that which says—

> "The use of lime without manure,
> Will make the farm, and farmer poor."

There is much truth in this saying, and it will be well to see the reason for it. One important action of lime is bringing into a useful condition any organic matter which is in the soil. It therefore uses up a certain portion of the organic matter, and by its continued use, the organic matter of the soil would be practically exhausted, unless fresh supplies of organic matter were from time to time added to the soil. Under a good system of husbandry, the increased produce of the land leads to an increase in the quantity of manure, and this finds its way back to the land. If, however, the lime be allowed to work out the organic matter in the soil, and no proper return be made to the land, then the land suffers very seriously. Hence it may be taken as a rule, to which there are very few exceptions, that the larger the quantity of lime that is used, the more farm-yard manure should also be supplied. The successful cultivation of the land is throughout a well-balanced system, and any departure from an equal-handed course of procedure will soon show itself by the decreasing produce of the land.

116. It was at one time the general practice for lime and farm-yard manure to be used at or about the same time. The practice was, however, loudly condemned in the early days of agricultural chemistry, for it was shown that if lime were added to farm-yard manure, its ammonia would be scattered into the atmosphere, and it was thereby practically lost. Here was an instance of the misapplication of a truth, from overlooking the controlling influence consequent upon this action taking place **in the soil.** We have already seen (107) that the action of caustic lime upon a mixture of farm-yard manure and soil produces a most valuable fertilizer, instead of causing a loss of ammonia. To avoid all possibility of danger, these manures should be added to the soil *at different times.* The farm-yard manure should be ploughed into the soil in the first instance, and the lime may then be spread on the surface and harrowed into the land.

117. The land in many cases receives its supplies of lime in a less powerful form, viz., in the various forms of **carbonate of lime. Chalk, marl,** and **shell sand**, are instances of this kind. The practice of applying chalk to the land has very generally a two-fold object in view. It adds to the land a supply of lime, and if it be freely applied it also alters the

general character of the soil to which it is added. The lime thus added to the land is in the form of carbonate; it has none of the energy which distinguished the quick-lime. In some respects it is capable of assisting the fertility of the land as much as the caustic lime; but it requires more time to accomplish its work. It neutralizes any organic acids in the soil, it contributes a supply of lime as plant food in a manner very similar to burnt lime, and it exerts a powerful influence upon the mechanical condition of the soil, although in a somewhat different manner.

118. Another large and valuable source of lime is found in a class of earths, known as **marls.** These always contain some carbonate of lime; but the quantity varies greatly, some having about 6 or 8 per cent., whilst others contain 80 per cent. of carbonate of lime. They differ also in the proportion of phosphate of lime and of potash which they contain. The quantity and composition of the silicates present also vary very greatly. The value of a marl is therefore entirely regulated by the fertilizing matter which it contains, and the mechanical influence which it is capable of exerting upon the soil to which it is applied. For a long time these differences in the composition of marls were not understood. Farmers found by the use of marls, that one was better worth drawing ten miles than another marl was worth drawing one mile, and they persevered in their practice. When, however, by the aid of chemistry the difference in their composition was shown, then the mystery was fully explained, and the evidence of practice fully justified.

119. The question is frequently asked, How am I to know whether lime should be used as caustic lime, or as carbonate of lime? To determine this question you must decide upon the result you wish to obtain. If the land should be a sandy soil, with very little organic matter in it, and very weak powers of vege-

table growth, you will conclude that this is not a case for the use of caustic lime, because lime in that form will exhaust the organic matter present, and there is evidently none to spare. In such a case, it is therefore more than probable that its use in the form of chalk or marl, will not only give the required supply of lime, but it will give greater firmness and power to the soil. Caustic lime would probably do more harm than good, whilst in the milder form of chalk or marl it would be highly beneficial.

120. As another illustrative case, we will take a strong clay soil; here it is more than probable that the preference would be given to the use of caustic lime, because of its more perfect action upon the inorganic matter. It is, however, quite possible that the use of chalk might be less expensive, and although a less desirable form of lime, it might be chosen for this reason. Yet, even in such a case, it must be remembered that the influence of the chalk upon the clay would have been very much increased if it had been burnt.

121. As a general rule, it may be taken that caustic lime should not be used if there is a scarcity of vegetable matter in the soil, and if it be light, and porous; but if there be a large quantity of organic matter, or if the soil be heavy and tenacious, then lime ought to be used in the caustic form. If you once understand the special action of lime in the two conditions of caustic and carbonate, you will have little difficulty in determining which is the more desirable form. It must, however, be remembered, that the varying circumstances and conditions of soil, climate, and the system of husbandry, call for judgment and local experience. For the present, at any rate, science must be, to a great extent, limited to an explanation of successful practice; and when an apparent conflict arises between them, science must be content to indicate the truth, without claiming for itself any certainty as to

its accuracy. Many established local customs represented as theoretically erroneous, have been proved to be correct by a more perfect knowledge of the agencies which are in operation, and it is by no means improbable that similar cases may yet come under notice.

122. **Green manures** consist of crops grown for the express purpose of being ploughed into the land as manure. It is, in fact, manuring the land with vegetable matter. As plants draw nourishment from the atmosphere, the crop so grown for manure returns to the soil more than it took from the soil, and so far it enriches it. But whilst the leaves are thus accumulating stores of fertility from the atmosphere, the roots are actively searching for nourishment from the soil, and storing this within them. Hence, when the crop has been fully grown, a large quantity of plant food has been gathered together, and this accumulation or store of food is buried in the soil, ready for helping the growth of the succeeding crop. This is no loss of labor, for it is copying from the example of nature. We have noticed (10) that when first the surface of a rock has been broken into soil, some of the lower forms of vegetation fix themselves there. These can exist under greater difficulties than more highly organized varieties, and they act as pioneers, preparing the way for higher and more useful varieties. They gather from the atmosphere the elements of organic matter, and having organized these bodies, the plant dies, and leaves its organic matter in the new soil. The soil is now prepared for a better variety of plant, and it, in its turn, accumulates still larger supplies of organic matter. These having done their work, die, and so the work of enriching the soil goes on. This is green manuring, as true in character as any we can carry out.

123. **Rye, mustard, lupine, buckwheat, vetches, Italian rye-grass,** and **clover** are crops

which are employed as green manures; but the last three are as a rule too tempting as food to be entirely ploughed into the land, although a portion of such crops is often left on the ground, for this purpose.

124. Green manures have **a mechanical action** on the land, rendering it more open, aud therefore better prepared for the roots of plants to penetrate, and seek nourishment for the growing crop.

CHAPTER VII.

TILLAGE OPERATIONS.

125. These tillage operations very greatly contribute to the productiveness of any soil. They chiefly consist of **ploughing, stirring, crushing,** and **harrowing,** and it will be seen that each of these contributes to the required result by two distinct means—

By the greater freedom with which plants are enabled to seek for and obtain their food; and
By increasing the plant food in the soil.

The operation of **ploughing** brings up from beneath the surface, soil which has been buried, and thereby exposes fresh material to the atmosphere. Ploughing is usually limited to **a turning over of the soil** which has been previously under cultivation. When the subsoil is ploughed, it is distinguished as subsoil ploughing, but this is generally **stirred** and **not brought up** to the surface, because it frequently has harsh and acrid matter present. As a rule, very great caution is necessary in bringing up to the surface any of the subsoil, especially when it is at all of a sour nature. There must be some good reasons for these practices, and it will be well to search them out.

126. The first effect of **ploughing** is to give the

land a greater **looseness** and **friability** of character. Land gets a certain amount of firmness during the growth and removal of any crop, and it is for this reason necessary that the land should be broken up. Ploughing also becomes a preparation for other work, which breaks it up still more completely. If land has become hard and firm, it is not in a favorable condition for the roots of plants to penetrate and search for food. If, by the mechanical condition of the soil, the plant is prevented from exercising a freedom of growth, the yield from the crop must be thereby diminished.

127. Not less important than this is the increase in the fertility of a soil caused by its **exposure to the sun and air.** The soil upon the surface having had the benefit of this action, is in a good condition for being turned down, and the under-soil will be freshened by exposure. The soil becomes "freshened" as it is often termed, or refreshed by the oxidation of its particles, which have in many cases been reduced to a lower condition of oxidation during the time it has been covered up. The oxides of iron are examples of this action; when they are exposed near the surface to the sun and air, they become fully charged with oxygen, but when buried in the soil they give up some portion of their oxygen in the several decompositions which take place in the soil, and thereby they become again reduced to a lower form of oxide. Still they are hereby performing a most important duty, as they really become "carriers of oxygen," and in some cases convey ammonia also.

128. A still more important source of fertility is obtained by **bringing the double silicates of the soil (24) into contact with the atmospheric air.** These have the power of **absorbing ammonia from the atmosphere.** We have already explained (104) how strong is the preference shown for the formation of double silicates containing am-

monia, and if any other double silicate exists in the soil naturally, or has been produced there by any artificial means, such double silicate will, by exposure to the air, take in from the atmosphere a valuable store of ammonia ready for the next crop.

129. The exposure of the soil by ploughing also enables it to derive full advantage from the **frosts and rains** of winter. We have in this way a breaking up of the soil going on through many months, and much of the dormant matter of the soil is thus rendered active, and available for vegetation.

130. That which is accomplished by the plough is also favoured and promoted by those lesser operations, which assist in bringing the earth into a finer condition for the growth of a crop. There are times when **stirring** is preferable to the ploughing of the land. When land has been ploughed up before winter, and exposed to the winter's frosts, it is often better to keep the fine earth thus obtained upon the surface, rather than bury it. The use of a stirrer, whilst it moves the land, and gives it the looseness desired for the roots, does not bury the finely-broken earth which is on the surface, and which is most valuable as a seed-bed for the next crop.

131. When the surface of the land is not sufficiently fine for a seed-bed, then we find the **crushing of the roller,** and the gentle **stirring of the harrow,** assist in breaking the lumps on the surface into a finer condition. The **fineness of the soil** is a most important point, when required as a seed-bed in which seeds can make a successful growth. In a rough soil a small seed will fall from one lump to another, until it has got too deep in the soil to make proper growth, and it therefore becomes necessary, by the use of rollers, to crush the rough lumps in the soil to prevent waste of seed.

132. A fine condition of earth is also necessary for a seed-bed in order that the **early growth may**

be encouraged. For a certain time the seed supplies to the young plant which is being developed from it, all the nourishment the young plant requires, but the little rootlets will soon have to take upon themselves the duty of obtaining food from the soil, and unless the fineness of the soil admits of a close approach of these rootlets, they fail to establish the young plants firmly in the ground. Two distinct conditions are necessary for plant growth. **A fineness of the soil** such as has been described, and also **a moderate firmness,** whereby the plant is fixed in the land. Both of these conditions are secured by a judicious use of the roller.

133. In the succeeding stages of the plant's growth, various mechanical operations, such as **horse-hoeing** or **hoeing by hand labour,** are carried on with the object of maintaining the land in a free and open condition, so that air and moisture can enter, and the roots spread through the soil with freedom in their search for food. The same operations are also useful for **the destruction of weeds,** which would otherwise take the food intended for the cultivated plant, and occupy space which is most desirable for assisting a luxuriant growth of the crop.

134. Few operations carried out by the farmer, exercise a more decided influence upon other branches of work, than **the drainage of the land.** This drainage is carried out, by making in the land channels and water courses, which enable the water to escape from its imprisonment in the soil. So long as an excess of water is kept in the soil, every form of labor upon the land is rendered more difficult, and the growth of the crop is very much slower and less perfect than it otherwise would be.

135. As soon as these water courses or drains have been made, the water commences running into them, and the land thereby becomes relieved of the excess which previously existed there. As the water drains

away from the soil, so **air is drawn into the soil** to take its place; otherwise the water could not escape from the land. If you nearly fill a bucket with stones, and pour water so as to cover them, the air has no opportunity of gaining access to these stones; but if you make an opening in the bottom of the bucket, the water runs out, and as the surface of the water lowers so the air follows, and gains access to the stones. This simple illustration will show how it is that the construction of drains for carrying away the water, of necessity brings the atmospheric air into the soil.

136. As soon as the air is admitted to a newly drained soil, a great change takes place. The unhealthy decomposition which had been going on in the stagnant water, had caused an accumulation of organic acids which made the soil unsuitable for the growth of any of our cultivated crops. The entrance of the air, bringing with it the pure oxygen of the atmosphere, soon converts these organic acids into more useful forms. It also enables an action to be commenced upon the inorganic matter present, whereby some of its dormant elements are rendered active and useful for plant growth. Thus the first good result of drainage is to remove from the land the stagnant water it contained, and draw in the purifying atmospheric air to increase the fertility of the land.

137. The drainage of land also gives an outlet from the soil for any soluble matter which is injurious to vegetation. The passage of water through the soil gradually dissolves this out, and practically washes it from the land.

138. **A very marked difference** is observable in the temperature, or **warmth of drained,** and **undrained lands.** You are no doubt aware that evaporation necessitates the employment of heat. If a vessel of water be placed upon a fire the heat it receives first causes the water to boil. If the heat be continued the water does not get any hotter, but

the heat is now entirely used in converting water into steam, or evaporating it. Water which has to be evaporated from the soil, requires heat to accomplish the work, just as if that water were boiled away in a vessel, upon a fire of coal.

139. It has been calculated, that the water which has to be evaporated from an acre of undrained land in the course of a year, may be taken as equal to the work of from 200 to 300 tons of coal. The sun's rays which fall upon such land do not warm undrained land, and thereby encourage vegetation, for they have in the first place **to dry the land.** Every warm breeze which passes over it, instead of favoring plant life, is chilled by the evaporation of water. In fact the heat which ought to be used for stimulating the growing crop, is very largely employed in drying the land. Such lands are consequently recognized as **"cold."**

140. Drained land is warmer than undrained land for another reason. It is well known that, generally speaking, warm water is lighter than cold water, and will rise to the top of any vessel in which it is contained. Suppose a warm breeze passes over land containing stagnant water, the heat which is not employed in evaporating the water will warm it slightly, but the water thus warmed will remain at the top, and the heat will not be communicated to the soil beneath. On the other hand, suppose a cold breeze to pass over the undrained land, this will chill the water at the top, but the water thus cooled will immediately sink into the soil, and be replaced by the warmer water from beneath. Thus it robs the soil of a part of its heat. In land in which a proper circulation of water is secured, the warm rain, instead of remaining at the top and losing its heat uselessly, penetrates through the soil, and warms it. The influence of this increase of temperature upon the productiveness of the land is very striking. The harvest

comes several weeks earlier than it otherwise would, and corn of good character is grown where the land previously produced only a very inferior quality.

141. The next great advantage is **the more perfect use of any manure** which may be added to the soil. The healthy condition of the soil renders the use of lime, farm-yard dung, and artificial manures much more beneficial. If the land is too wet, these manures are to a great extent wasted, because there is no vigorous growth to utilize them, and their decomposition is of an unsatisfactory character. Until land has had good and proper drainage, it is almost useless to attempt its improvement by the use of manure. It would be better to use the manure upon land fit to receive it.

142. The same circumstances which make land more healthy for vegetable growth, also make it **more healthy for animal life.** This is largely due to the fact that a superior quality of herbage maintains stock more perfectly, and gives them a greater vigour of life, which is in itself a great protection against disease. An insufficient supply of proper food, greatly predisposes an animal for disease. Hence, just in proportion as land produces inferior food, deficient in nourishment, so the stock upon that land becomes unhealthy, and more liable to disease. In addition to this, the damp character of the land exerts a direct influence upon the animals kept upon it, producing various forms of disease.

143. The drainage of land reduces **the cost of all the tillage operations,** enables the land to be cultivated with much less labor, and it extends the time during which the work may be done.

CHAPTER VIII.

ROTATION OF CROPS.

144. The practice of agriculture has long proved the importance of regulating in proper order, the succession in which crops should be grown. It has been found that if some of our crops be grown upon the same land year after year, difficulties have to be overcome, for the crop to be kept in a healthy and luxuriant condition. It is commonly remarked by farmers that the land is "**sick**" of a crop, and clover is especially referred to in this way. If a field is "**clover sick,**" it is unwise to sow clover again until the land has become ready for it. The same influence has been noticed in connection with other crops; this has led to the crops being changed frequently, and experience has taught us much, as to the manner in which we may best make these changes.

145. The rotation of crops adopted in different districts, represents the experience derived by farmers as to the best order in which our crops should follow each other. The term "**rotation of crops**" may therefore be taken to mean, the order of succession in which our crops are grown. This is an exceedingly important matter, for it exercises great influence upon the success of farm operations, and it is therefore desirable that the conditions which influence these results should be clearly understood.

146. At one time it was thought that De Candolle was correct, in his explanation of the cause of land becoming "sick" of a crop. He had observed that when the same crops had been grown repeatedly in direct succession on the same land, they became unhealthy; that there was a want of vigour, and the produce became small. If, however, another kind of crop were sown, it seemed to thrive luxuriantly, where

the other pined away. He explained this by assuming that plants threw off excrementitious matter in the soil, which after a time became so very objectionable to the crop, that it became unhealthy and died. The excrement of one crop he considered to be even desirable for another crop; at any rate it was supposed to be unobjectionable. He based his explanation upon the assumption that plants treated the food they received somewhat in the same way as animals did, viz., that after making use of such portions of the food as were desirable, the residue was thrown off as an excrement. De Candolle's theory has, however, been generally set aside, as less satisfactory than that advanced by Liebig.

147. According to Liebig's views, the difficulty arose from **a want of proper food** for the plant, and he held that the plant became unhealthy and pined away, simply because the plant needed food which the soil could not supply. He supported this by showing the number of different substances which our cultivated crops required the soil to supply (41). He showed that when a soil was nearly exhausted of the materials which one crop required, it might still contain an abundant supply of food for another kind of crop. He was of opinion that whilst one crop would have had a short supply of food, there was an abundance in the soil for the other crop. The one crop might therefore fail, whilst the other would flourish. It has been generally accepted as one of the rules which should regulate the rotation of crops, that those **plants which required the same kind of food, should be kept as far apart as possible,** whilst those which require different supplies might follow each other.

148. The second rule is that **plants of the same habit of growth, and general character should not follow each other.** For instance, some plants strike deeply into the soil, and obtain

much of their food from the lower portions of the soil, whereas other plants send out their roots amongst the surface soil and are shallow rooted. Thus the clover roots strike deeply into the soil, and really enrich the upper soil, by adding to it matter drawn from beneath it. Wheat is found to grow luxuriantly upon land in which the clover has flourished. A good clover ley is a tolerably sure promise for a fine crop of wheat. This probably arises from two causes, which readily explain this well known fact. The clover has not drawn from the upper soil the food which the wheat requires, but has stored up in its closely matted roots, a large quantity of nitrogenous matter on which the wheat plant can feed. The roots of the wheat also find in the clover ley, freedom for their growth, amidst the supplies on which it has to rely for nourishment.

149. Another illustration of the conditions which influence the rotation of crops is shown in the case of beans following wheat; and the table already given (41) shows the substances drawn by each of these crops. Wheat requires a large supply of silicates, beans take one-tenth of the quantity; on the other hand wheat requires only about one-half the potash and phosphoric acid that the bean crop needs. So also amongst the white straw corn crops there is another difference observable, for whilst wheat roots deeply, barley roots shallow; and these crops therefore draw their supplies from two different layers in the soil.

150. **The Norfolk rotation,** or the **four years' course** of cropping, is a good representative system, and one which has probably been more largely, and more generally adopted than any other. It consisted of the following course of crops:—

1st Year,	,,	Turnips, or other Root Crop.
2nd	,,	Barley.
3rd	,,	Clover.
4th	,,	Wheat.

The advantages of this course were as follows:—The turnip crop gave great facilities for thoroughly cleaning the land; it was also a convenient time for the use of manure, and the root crop flourished under these circumstances. The land was thus prepared for barley, and for the clover seed sown amongst it, for it was **clean** and **in good condition.** A strong growth of clover was tolerably sure to check the growth of weeds, and when the clover ley was broken up for wheat, the land was in fine condition for its growth. Thus every crop was exerting a favourable influence upon that which had to follow.

151. After a few years it became necessary in many cases to alter the system. Some farmers whose land was not as good as other soils, or who did not add fertilizing matter as liberally as other farmers, found that their crops were falling off in their yield, and that they must have corn less frequently. In such cases the clover was allowed to remain a second year, and this made it a **five years' course.** Thus—

1st Year,		Turnips, or other Root Crop.
2nd	,,	Barley.
3rd	,,	Clover.
4th	,,	Do.
5th	,,	Wheat.

152. But, while some farmers had to have corn less frequently, others found the land becoming so much more fertile, that they were obliged to grow more corn from it. The barley crop was found to grow so strong and coarse, that it lost quality. Farmers therefore sowed wheat after the turnips, and this crop made good use of the abundant supply of fertilizing matter in the soil. The barley was sown after the wheat crop, and grew more steadily, and yielded a higher quality of corn. This gave a **second form of five years' rotation,** in which more corn was grown in consequence of the high cultivation of the land. This rotation was—

1st Year, Turnips, or other Root Crop.
2nd ,, Wheat.
3rd ,, Barley.
4th ,, Clover.
5th ,, Wheat.

153. It would be impossible to describe here, all the various rotations which are in use, but these are taken as representative cases, showing, in the first place, a course of cropping founded on sound principles, and afterwards altered for equally good reasons, so that the growth of corn should in the one case be less frequent, and in the other instance more frequent.

154. In some cases we find what must be called **a bad rotation,** for instance—

1st Year, Oats.
2nd ,, Do.
3rd ,, Wheat.
4th and following years, Clover or Grass Seeds.

Here we have all the conditions of a good rotation (150) set aside. The land did not have proper cultivation for rendering it free from weeds. The application of manure would, under such management, be excessively small, even if any were used, and the repeated growth of corn without proper cultivation and manure, is alike to the injury of the land and the farmer. The land when laid down in clover or grass seed would be as foul as it well could be, instead of being so clean that the clover could fully occupy the ground, and yield a rich and nutritious crop.

155. The rotation adopted upon a farm must also be regulated so as to secure an **equal distribution of the work** throughout the year, and to give that **variety of food and litter** which the system of farming renders necessary.

156. The success which has attended **the continuous growth of corn** appears, at first sight, to be in direct opposition to the theory of the rotation of crops we have referred to. It has been most satisfactorily

shown that, under certain circumstances, corn can be successfully and profitably grown upon land, year after year, for a long period of time. This, however, admits of a ready explanation. If you refer to the quantities of inorganic matter removed from the soil (41) you will see that wheat makes a large demand upon the soil for silica; but when you compare the quantities of phosphoric acid, lime, potash, and soda removed by the several crops, you will observe very great differences between that which is necessary for the wheat crop, and that required for the other crops there referred to. For instance, a crop of beans takes nearly double the phosphoric acid required for wheat, and a turnip crop takes three times the quantity. A crop of beans takes more than three times as much lime as a crop of wheat, and a crop of turnips and clover each takes ten times as much. So also with potash, beans taking four times the quantity required by wheat, turnips taking eight times as much, while clover takes double the quantity; and so also in the case of soda. Without laying too much stress upon the exact proportions so drawn from the land, it is evident that, whilst wheat makes a larger demand upon the soil for silica, comparatively speaking, it requires but a moderate supply of other inorganic fertilizers.

157. In fact, the continuous growth of wheat withdraws from the land a constituent which occurs practically in an unlimited quantity. But it must be remembered, that the successful conduct of this practice necessitates that **thorough cultivation of the soil,** which makes a large quantity of the silica existing in it in a dormant condition take an active form, and thereby become available for the growth of the crop. A supply of silica cannot thus be made available from all soils, as for instance in the case of sandy soils, although the silica exists in these in a very large proportion. The soils upon which this result is obtainable, are those which contain a large supply of silica in

the form of clay, or silicate of alumina—and especially those in which the double silicates are found. It is, however, necessary, in almost every soil, to supplement the good influence of thorough cultivation, by the judicious use of manure.

CHAPTER IX.

LIVE STOCK.

158. The system of farming adopted must determine the kind of stock which is kept upon the farm. In some cases, dairy cows and pigs will be the live stock kept, in other cases, sheep, and some farms will have cattle; others, again, will adopt a mixed husbandry, and have some of each variety. Without, at the present time, going into detail on the relative advantages of each, it may be sufficient to remark, that whatever may be the kind of stock kept, it should be of good quality, and suited to the district.

159. Upon the good management of the live stock of the farm, much of the farmer's success depends; and it is satisfactory to know that that which promotes the comfort of the stock, also increases the profit they produce. Harsh and cruel treatment should be recognized as decreasing the profit which any animal will produce, because it is punishing to the stock. The suffering undergone by an animal, involves a corresponding loss to the owner. If no higher motive than profit exists for careful and kind treatment, this ought to be enough; but it cannot be too much impressed upon all having the care of live stock, that some better motive should guide them.

> "A merciful man unto his beast is kind,
> But brutal actions show a brutal mind."

Kind and careful treatment of stock, is one of the foundation stones of good and profitable management.

160. The supply of food should be regular, and of such a character as to keep stock steadily improving. Some few years since, it was very common for the stock kept through the winter months to lose nearly all the flesh they had gained in the preceding summer, simply because sufficient food was not supplied to prevent this waste of the body. It is now known to be **not only cruel,** but **unprofitable,** and such bad management is, in consequence, rarely seen at the present day.

161. **Improvements** have been made in live stock, whereby they have become more economical producers of meat. A certain quantity of food eaten by some of our "improved breeds," will produce more meat than if it were eaten by one of the original unimproved stock. The remark applies to cattle, sheep, and pigs, for in each similar modifications have been produced, although differing in degree.

162. Before the great changes, which we call "improvements," were stamped upon the various breeds of stock, there were many points of character in which they agreed. They were generally very active in their habits, able to travel great distances without much trouble, wild and restless in their disposition, fond of liberty, hardy in their constitution, and were able to give abundance of milk to their offspring.

163. In our "**improved breeds**" this has been greatly altered. The activity of the body has been diminished, and the animals have become indisposed to much exercise. Instead of ranging over wide tracts of country for their food, they look for its supply without having to take much labour to secure it. They rejoice in quiet and peaceful lives, with abundance of food, and the least possible amount of trouble. They are tender and delicate, they breed with great difficulty, and have a very small supply of milk

for their offspring This is the change which has been accomplished in our "improved breeds" of stock, and many will be disposed to inquire, **wherein does the improvement consist?**

164. The actual improvement consists, in a **greater economy in the production of meat** from vegetable food. If a certain quantity of corn, or roots, or clover had to be converted into meat, with the least possible loss of time and material, then we should succeed best, if we made use of an animal of an improved breed, to do the work. Here we should find the animal quietly and placidly taking its food, and then resting whilst that food was undergoing the changes necessary to convert it into the flesh of that animal. As soon as this had proceeded for a certain time, fresh food would be supplied, and the work of growth encouraged; finally, when it was thought desirable to complete the fattening of the animal, suitable food would be given, and thus we should be able to produce early maturity, and thereby obtain meat in its cheapest form. In other words, we have made our several breeds of farm stock into excellent machines for the production of meat. In doing so we have deprived them of much of that energy of life, and hardy character, with which they were prepared to withstand the difficulties and the dangers of a life, in which they had to take care of themselves, far more than they were taken care of.

165. Thus we are able to control the character, and the form of our domesticated animals, and produce very extraordinary variations from the original type. This success is not attained by sudden changes, but by taking advantages of favourable peculiarities, encouraging their development, and then rendering them more permanent. It must, however, be remembered, that we can only control the peculiarities of animal life, by such methods as the laws of animal life permit. In this way we have obtained improved breeds of cattle, sheep, and pigs altogether different in shape, in

their habits of life, and in their constitutional character, from the original breeds from which they were obtained. These variations must, however, be regarded as unnatural and abnormal conditions, and as being obtained for the more economical production of meat. We cannot run contrary to the course of nature, yet, like mariners who have adverse winds to deal with, we can "tack about," so as to be carried forward by the functions of animal life, to the attainment of a result totally different from that which the same agencies would have produced, had the animal existed in a wild condition.

166. Fat is produced from the **non-nitrogenous** portions of the animal's food, and its chief use in the animal body is to **maintain the heat of the body.** The temperature of the animal body is higher than the air in which it usually lives. An ox has a body-heat of 100° Fahr., and for its healthy condition this temperature should be maintained. If there were no internal source of heat, the warmth of the body would fall to that of the surrounding air, and this does take place after death. The lungs of the animal assist largely in this very important duty. The oxygen of the atmosphere being drawn into the lungs, is thus enabled to act upon the non-nitrogenous matters which are in the blood. These matters contain a large quantity of carbon, and by the union of the oxygen of the air with the carbon of the food, we have carbonic acid formed. The animal therefore draws in oxygen and throws off carbonic acid. The lungs thereby do the work of a pair of bellows, and by the addition of oxygen to the blood the carbon is gradually burnt off or oxidized, as the blood is circulating through the body of the animal. The following analysis of atmospheric air and the breath of an animal, given by Playfair, will sufficiently illustrate this fact:—

	Composition of Atmospheric Air drawn into the Lungs.	Composition of the Breath thrown off from the Lungs.
Nitrogen,	79·16	79·16
Oxygen,	20·80	16·84
Carbonic acid,	·04	4·00
	100·00	100·00

This shows a very small quantity of carbonic acid in the atmospheric air, and how greatly the carbonic acid is increased by a single respiration of the animal. We have therefore, by the healthy action of the lungs upon blood properly supplied with non-nitrogenous matter, an internal source of heat which maintains the warmth of the body, up to a healthy standard.

167. Two conditions are essentially necessary to secure this result—

The lungs must be sufficiently powerful, and,
The blood must contain sufficient heat-producing matter.

The demands made for the maintenance of the warmth of the body, are entirely regulated by the loss of heat from the body. If the loss of heat be great, the demand for heat is great also; and if the loss of heat be small, there is only a small supply needed. If the air should be very cold, there will be a great loss of warmth, and the demand for internal heat will be great; but if, by sheltering the animal from the cold air, the loss of heat is reduced, then the demand for internal heat will be decreased also. It is therefore quite within our power to reduce the loss of heat from the body, and **thereby to economize the fuel or heat-producing matter of the food.**

168. The demands made upon the lungs and the food, are therefore entirely regulated by the waste of warmth from the body. If there be plenty of heat-

producing matter in the blood, the lungs work away at it, and purify the blood just to that degree which is necessary for keeping up the warmth of the body. **Shelter** from the cold is therefore desirable upon economical grounds, for thereby less of the heat-producing matter in the blood is thus used, and that which remains can be stored up in the animal as fat.

169. The formation of fat is also encouraged by **the motion of the body being limited,** for as motion stimulates the lungs to greater activity, so a larger proportion of the heat-producing matter is burnt off, and less remains to be converted into fat.

170. The **size of the lung** influences the formation of fat, for the quantity of oxygen drawn into the lungs, and dissolved in the blood is regulated thereby. A largely developed lung will more fully oxidize the heat-producing matter of the blood than a small lung, and hence it has been found that the animals which fatten most readily have the smallest lungs.

171. It has also been observed that **a small or inactive liver** promotes fattening, but there are limits which cannot be passed without fatal consequences. Sheep which have the rot in the liver, fatten with greater rapidity during the first eight or ten weeks after they have taken it, than previously, but after this length of time the liver becomes so rotten, that the general health suffers, and the animal pines away and dies.

172. The management carried out for establishing our improved breeds, encourages the formation of small lungs and small livers. By preventing the animals taking much exercise, these organs also become slow in their action and naturally sluggish. A larger proportion of the heat-producing matter is left, and becomes stored up in the animal as fat. We therefore consider such animals good fattening animals,

because we get a larger quantity of fat formed from a given quantity of food.

173. It is necessary now to look at the other side of the picture. Such animals are **delicate,** and require more care and protection than others. We have given these animals small lungs, and sluggish livers, and consequently the power of the animal to maintain its warmth is reduced. If such animals are exposed to cold weather, we soon find that they have reduced powers for maintaining their warmth, the healthy condition of the body suffers, and the animal becomes subject to disease. The conditions which render animals energetic, active, and hardy, have in these cases been modified to make them good producers of fat, and in proportion as we have succeeded in this attempt, so we have produced a weak and delicate constitution.

174. These circumstances fully account for what is known as **a loss of constitutional strength.** If you seek for this, you find it where the laws of animal life exercise their full influence. The wild, undomesticated animal, possesses a healthy and vigorous system, and every part of his body possesses a thoroughly healthy character, and thus the full energy of constitutional strength is maintained. Nature rebels against our "improvements" in the several breeds of stock, and just in proportion as we are successful in producing **unnatural** specimens so we find the laws of animal life coming in to check us in keeping up the succession.

175. Shelter and economy of food, should never be carried out at a sacrifice of the **proper ventilation of buildings.** It has been shown that animals draw into the lungs atmospheric air, use a portion of the oxygen, and throw off carbonic acid. This **carbonic acid** is a very **dangerous** gas, for no animal can live in it, and it should therefore be carried off from the building. An instance showing the deadly character of

this carbonic acid, occurred a few years since on board a vessel which was bringing sheep from Holland to England. In consequence of stormy weather, the sheep were placed below deck, and the hatches closed so that they could get no fresh air. When the hatches were opened it was found that the sheep were dead, and they had to be thrown overboard. They had been **poisoned**, by breathing the carbonic acid thrown off from their lungs, instead of breathing pure air.

176. Although the action of the carbonic acid is seldom immediately fatal, we still find considerable injury arising from its being allowed to remain in the building. This injury is very much more serious than it otherwise would be, because the ill effects are not so easily traced to the proper cause. If the carbonic acid cannot get away, fresh air cannot obtain entrance, and it is only a question of how long the animal can exist. If there be no supply of fresh air the animal must die. It is very seldom, however, that the evil influence continues long enough to be fatal, but we very frequently find such a deficient supply of fresh air, that the carbon of the food cannot be burnt off by the lungs, consequently accumulations take place on the **lungs** and these **become diseased**. Whenever we fully understand the wide extent of loss which arises from the buildings in which cattle are kept, not being properly ventilated, we shall be astonished at its magnitude. The prevalence of diseased lungs in farm stock arising from a want of proper ventilation, is increasing year by year, and as yet the cause is but imperfectly recognized. If the carbonic acid be once looked upon in its true light in relation to animal life, as **a poisonous gas**, there will be a greater willingness to adopt measures for assisting its departure from buildings in which live stock are kept, and for securing for them a free supply of **pure air.**

CHAPTER X.

FOOD OF FARM STOCK.

177. The food of farm stock comprises numerous substances, which differ very widely in their character and composition. The extent to which cultivation, soil, climate, and manure affect the nutritive value of our crops, is a subject of the deepest importance for the consideration of farmers, and it may be hoped that, as the principles regulating vegetable growth become more generally known, we shall be able to increase the value of the food employed. We have already (32) referred to the several substances which we find in vegetable matter, and shown that they are divided into two groups—nitrogenous and non-nitrogenous.

178. The **non-nitrogenous** bodies—starch, gum, sugar, and oil—have two distinct duties.

The maintenance of the warmth of the body, and
The production of fat.

It is from the food, that the blood obtains its supply of the materials, by which the warmth of the body is kept up by the respiration of the lungs. It is more than probable that when starch, gum, and sugar are present in the food, these are first acted upon for the production of animal heat, but if these substances are absent, then the oily matter of food has to perform this service. These bodies may therefore be regarded as the **heat-producing** matters in food.

179. The **nitrogenous** substances in food—albumen, casein, and fibrin—have two other perfectly distinct duties to perform. They have

To repair the waste of the body, and
To develope muscular growth.

The first duty draws our attention to the waste of the body, which is constantly going on. Every movement of the body causes a waste of the part exercised. If the strain or effort be violent, the waste of tissue is greater than if the movement be gentle. The waste is, however, quickly repaired, and, as if to prepare that part of the body for future demands, it is actually strengthened. Hence, although exercise causes a waste of the tissues, it tends to increase the strength of the part exercised. All are familiar with the well-known strength of the blacksmith's arm, resulting, as it does, from severe exercise; and in contrast with this we have the weak and feeble arm, which has been kept from exercise. The waste of the body makes its demand upon the several substances of this nitrogenous group, and this is the first duty they have to perform. Any surplus which remains is available for muscular growth. This group therefore represents the **flesh-forming** matter of food.

180. There is another class of bodies present in food, and these are known as the **mineral** matter of food. Their chief duty is to supply materials for the growth of the **skeleton.**

181. The various articles of food which we employ for feeding farm stock generally contain a mixture of different bodies, belonging to two, and sometimes to three of these groups. Our judgment upon the action of food, is therefore influenced by what we know of its composition. If, for instance, there should be none of the flesh-forming bodies—the nitrogenous group—present, then it would be impossible for flesh to be formed. We are not justified, however, in saying that if none of the heat-producing matters—the non-nitrogenous group—are present, that it would be impossible to maintain the warmth of the body. There is reason to believe that the nitrogenous group, which contains (in addition to nitrogen) carbon, hydrogen, and oxygen, the elements of which the heat-producing

group are constituted, can, on an emergency, contribute matter for the maintenance of warmth. It is not, however, their legitimate duty, and when it is performed by them it is done at a sacrifice of economy.

182. Before we proceed to notice the economical use of food it will be desirable to outline in a very brief manner, the very important **changes which food has to undergo**, before it can be utilized for the purpose of animal life. For this purpose we will take cattle as the basis of our comments. A bullock has four stomachs, of which the first, which is known as the rumen, is the largest of the series; it is simply used for receiving the fresh gathered food. Whilst the food remains in this stomach, it receives moisture from the **saliva**, which is passed down the gullet from the salivary glands which secrete it. The structure of this stomach keeps the food gently moving, and thereby assists the softening of the food, and the general action of the saliva. The preparation thus commenced in the first stomach, enables the food to pass into the second stomach, and as soon as the animal is prepared to ruminate the food, or as it is commonly called, "chew the cud," the food passes again into the mouth, for the purpose of being more thoroughly masticated or chewed.

183. This **mastication** has to accomplish two distinct objects, it has

To reduce the food into a fine condition, and also
To bring it under the action of the saliva.

It is necessary that the food should be reduced to a very fine condition, in order that every portion of it may be the more perfectly acted upon in the process of digestion. By digestion we mean that action upon the food, which prepares it for being taken up in the blood, and thus contributing to the growth of the animal. But this mastication has also the duty of securing the full action of the saliva upon the food. This

saliva must not be regarded simply as water which moistens the food, for it has the power of converting the starch of food into sugar. This chemical change is commenced whilst the food is in the first stomach, and it is materially advanced under the process of mastication.

184. The food therefore having been gathered in, softened and fully masticated, when it has thus become sufficiently soft and sweetened, it is passed into the third stomach. In the third stomach the food is simply allowed to macerate or soak for a time, and it is probable that the starchy matter of the food is here more completely changed into sugar. The softened and sweetened food, which is now a semi-fluid mass, is passed on after a time into the fourth stomach for further preparation. The first stage is now complete, for the food has been **finely broken up, softened,** and **its starchy matter largely turned into sugar.**

185. In the fourth stomach, we find that the membrane which lines it, has the power of pouring out, like perspiration on the skin, a liquid which has been named **gastric juice.** It is a clear, colourless liquid, but with an acid taste, arising from the presence of hydro-chloric and lactic acids. It also contains a peculiar organic compound named pepsin. The gastric juice has a very strong power of dissolving the nitrogenous portions of the food, and through its influence the food undergoes this further change. The semi-fluid mass is at this stage called the **chyme.** This is the second stage in the process of digestion, and the chyme therefore represents the original food softened, finely divided, with its starchy matter turned into sugar, and **the nitrogenous portions of the food brought into solution.**

186. Another stage has to be accomplished, for in the chyme we have the fatty matter still floating about as oil, and this has to be prepared for being

taken up by the absorbent vessels. As soon, however, as the formation of the chyme has been duly perfected, it is passed from the fourth stomach into the duodenum, which is the highest part of the small intestine, and here it meets with two other fluids, the **bile** and the **pancreatic juice.** The bile is a secretion formed by the liver, and is in reality a soap with an excess of soda. The pancreatic juice is secreted by the pancreas or sweetbread. This juice is colourless and transparent, and has the same power as the saliva, for converting any starch into sugar. It is therefore ready to complete any work left unfinished by the saliva in the first stage. The bile, however, has entirely new work to accomplish, viz., getting the oily matter of food blended with water.

187. You know that common soap carries with it a certain quantity of soda, and if used upon any greasy matter, it enables the grease to be mixed with the water used for the purpose of washing, and thus the oily matter is removed in the water. The bile is an animal soap, and as soon as it is brought in contact with the oily matter floating in the chyme, the soda it contains enters into combination, and **the oily matter of the original food is blended with the water.** After the chyme has been thus acted upon by the bile it is called **chyle,** and this association of names may help you to remember their proper sequence.

188. The mineral matter found in food is under the same conditions, and especially by the action of the gastric juice, prepared for entering into the circulation, and thus the blood also becomes charged with the inorganic matter which is required.

189. We have now got each portion of the food blended with water, viz., the starchy matters of the food, the nitrogenous substances, the oily portions, and the inorganic matter. These supplies of food are always accompanied by other matters, such as cellulose

and woody fibre, which pass away in the excrement, after the useful portions have been separated. This separation of valuable food materials, is carried out by a series of absorbent vessels, and being passed into the blood is conveyed to the lungs where the oxidation by the atmospheric air is commenced.

190. We have now arrived at an intermediate stage, and having introduced the nutriment of food into the blood, we may indicate its course onwards until made use of by the animal. Its duty commences in the lungs and bloodvessels, for in the oxidation which there takes place, we have carbonic acid largely formed, the temperature of the blood thereby maintained (166), and the warmth of the animal is provided for. From the lungs, the blood is pumped by the heart through arteries, which terminate in beautiful hair-like tubes, called capillaries. These form a complete network throughout the body, and they are so generally distributed that even the prick of a pin reveals their existence. These capillaries allow the **serum of the blood,** which contains the **fibrin** in solution, to pass through and exude from them, and when that matter is brought into contact with living tissue, it is made use of for its growth. In the same way, the **oily matter in the blood** is rendered available for the growth of **fatty tissues.**

191. The growth of the body is therefore dependent upon the food which the animal receives, and upon that general condition of health, which enables the processes of digestion and absorption to proceed in a proper manner. A considerable portion of the food is necessary for the maintenance of the body in a healthy condition, but this **does not contribute to its growth.** The warmth of the body must be kept up if the animal is to be preserved in health, and this necessitates the use of a certain amount of non-nitrogenous matter, without any increase of growth. In the same manner the ordinary waste of the tissues of the body must be

restored, and this necessitates the unproductive use of a certain quantity of nitrogenous matter. It is a sort of **life tax** which has to be paid in order that the animal may be kept in health and strength to perform some useful duty.

192. In order that some idea may be formed of the extent to which the elements of food are used for the maintenance of the body in health, independent of any production of flesh, we will take the case of a cow in milk, which received a known quantity of food during twenty-four hours and (assuming, as may fairly be done, that she remained the same weight at the end of the day as at the beginning) disposed of it in the following manner. The food given consisted of 120 lbs. of water, 30 lbs. of potatoes, and 15 lbs. of grass. (*Boussingault.*)

	Composition of the Food.	Composition of the Milk.	Composition of the Dung.	Passed through the Lungs, Kidneys, and Skin.
	lbs.	lbs.	lbs.	lbs.
Water,	143·92	14·78	48·83	80·31
Carbon,	9·62	1·25	3·42	4·95
Hydrogen,	1·18	·20	·42	·56
Oxygen,	8·06	·64	3·01	4·41
Nitrogen,	·38	·09	·18	·11
Ash,	1·84	·11	·96	·77
	165·	17·07	56·82	91·11

In this case we have—

17 lbs. utilized as milk.
57 lbs. indigestible matter.
91 lbs. the waste of the body.

165 lbs. weight of food given.

193. The food which is necessary for **supplying the waste of the body** is variable, because the cir-

cumstances and conditions which influence the body are variable. More non-nitrogenous matter is used in cold weather than when it is warm, and if there be much exercise taken by the animal, the demand for nitrogenous matter is increased in proportion. It is, however, a demand which must be satisfied before the animal can either make growth, or add any fat to its body.

194. Our only true foundation for determining the feeding power of any food, is by the evidence obtained by experimental trial. The following table shows the increase in the live weight of the animal, obtained from the several varieties of food named:

		Increase in live weight
150 lbs.	Swedes consumed in the field . . .	gave 1 lb.
100 ,,	Swedes fed in field, with shed to run under	,, 1 ,,
12 ,,	Good clover hay	,, 1 ,,
8 ,,	Beans	,, 1 ,,
8 ,,	Peas	,, 1 ,,
7 ,,	Oats	,, 1 ,,
6 ,,	Barley	,, 1 ,,
5 or 6 ,,	Linseed cake	,, 1 ,,
4½ ,,	Linseed cake and peas in equal proportion	,, 1 ,,
3½ ,,	Linseed cake and beans	,, 1 ,,

195. A distinction must be drawn between an **increase in the live weight** and an **increase in flesh.** The general growth in the body necessitates a development of the digestive organs, and other parts of the body constituting the offal, as well as an increase of flesh, bone, and fat. The former mnst be looked upon as necessary machinery, and the latter as the product obtained.

In Sheep, 14 lbs. of live weight usually consists of 5 lbs. offal and 9 lbs. meat.

In Cattle, 14 lbs. of live weight usually consists of 6 lbs. offal and 8 lbs. meat.

It has been already stated (194) that, under certain circumstances, 150 lbs. swedes produced 1 lb. increase in live weight; therefore, 2,100 lbs. swedes would be equal to 14 lbs. increase in live weight, or 9 lbs. of mutton.

196. We thus see that food has two drawbacks in its conversion into meat. It has to pay a life-tax for maintaining the animal in a healthy condition, and it has also to construct out of the food the machinery necessary for the conversion of the residue into meat. But whilst we fully recognize these unavoidable duties, they distinctly indicate the economy of making a full use of the advantages thus purchased. To keep an animal intended for the production of meat, in such a manner that it makes no progress, is practically paying for a privilege which you do not make use of. If, on the other hand, having paid out of the food these necessary demands, care be also taken to give the animal such food as shall promote rapid production of meat, you then take advantage of the opportunity you have purchased.

197. From the same point of view we may also more fully realize the value of artificial food such as linseed cake, corn, &c., in acting in a **supplemental capacity**. For instance, assuming an animal feeding upon grass or roots to be receiving therefrom **just sufficient** food to keep it from losing weight, the daily demand of the body will have been thereby satisfied. If such an animal received some additional food, it would be able to **turn that supplemental food into a marketable form, with much less loss of useful material.** In the one case the toll is paid for an empty cart; in the other case we pass a profitable load. But if a given quantity of good food were supplied to an animal at a rate **not equal to the waste** of the body, then we not only do not get any increase of live weight for the food used, but the **animal loses** weight. In fact, it makes up the deficiency in the supply by feeding upon itself, and if the treatment were continued long enough, the nimal would starve for want of a **sufficiency of**

food. You must therefore fully realize the fact, that although food is **capable** of yielding a certain increase of live weight, the result **actually obtained** depends in part upon **the rate of supply.**

198. It was at one time generally considered that the percentage of nitrogenous, and non-nitrogenous matter in a food, indicated its powers of producing flesh and fat respectively. We have proved by experiment the actual feeding powers of different kinds of food (194), but this does not support the opinion, that analysis now indicates the quantity of flesh and fat which will be produced by a food. If, however, we know what any food of a given quality will produce, we may rely with confidence upon an analysis showing whether any particular sample is likely to produce larger or smaller results. Analysis is a safe guide for determining the difference in value between two samples of food, say of linseed cake; but we must rely upon actual experiment for proving its value as food. This will be more fully confirmed by the facts stated in the next paragraph.

199. It has been shown by repeated trials that by a **judicious combination** of different kinds of food, we can obtain a much larger production of flesh and fat, than by using the same quantity of the same food separately from each other. For instance, it has been stated (194) that 8 lbs. of beans or 6 lbs. of linseed cake are each capable of producing 1 lb. of increase in live weight, but it has also been shown by direct experiment, that when these foods are mixed and given together, then we just get **double** the produce. Thus 8 lbs. of beans would produce one pound increase, and 6 lbs. of linseed cake would produce a second pound, but if the beans and linseed cake are given as **a mixed food,** they produce 4 lbs. increase of live weight. In forming an estimate of the results which are likely to arise from the use of any artificial or supplemental food, it must therefore be borne in mind,

that these results are largely influenced by a judicious combination of foods **possessing different qualities,** the one being essentially a fat-producing food, (such as linseed cake, linseed, barley, &c.,) and the other a flesh-forming food (such as beans, peas, lentils, &c.). It appears as if the growth of flesh and fat took place more rapidly when the materials are abundant **for both,** than when the supplies are limited to that which is necessary for the one or the other.

200. In this mixture of food, it is desirable to regulate the proportions in accordance with the **age of the animal.** If it be a full-grown animal which is being fattened, less flesh-forming food will be necessary than if the animal were making great muscular growth. Still even in such a case a moderate use of flesh-forming food will be found economical. In the case of a young and growing animal, in which the growth of muscle (or flesh) is taking place at the same time as fat is being formed, the necessity for **both** is evident. The successful production of flesh and fat is therefore dependent upon a proper supply, and a judicious use of the necessary materials in the food, and upon the adaptation of the animal system for its economical conversion into meat.