ELEMENTS

OF

SCIENTIFIC AND PRACTICAL

AGRICULTURE,

OR THE

APPLICATION OF BIOLOGY, GEOLOGY AND CHEMISTRY TO AGRICULTURE AND HORTICULTURE.

INTENDED AS A TEXT-BOOK FOR

FARMERS AND STUDENTS IN AGRICULTURE.

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PREFACE.

About two years since, the author turned his attention to Agricultural Chemistry, with a view to prepare a text-book on scientific and practical Agriculture. His particular object was, to furnish facilities for the introduction of Agriculture, as a branch of study, into some of our academies and high schools. This design has been steadily pursued; although, at the time of commencing his investigations, the subject was involved in so much obscurity and uncertainty, that he often despaired of being able to prepare a book, which would be of any real service to those for whom it was intended.

The late works of Liebig, Daubeny, Johnston and Dana, together with the Geological Reports, in most of the States, have thrown a flood of light over the whole subject; and although we cannot affirm that *all* is known which it is desirable to know, still, many fundamental principles are established; and we have the materials for constructing the most important and useful science of modern times.

The avidity with which the public mind have seized everything which promised to throw light on the art of husbandry, is an encouraging indication, that it begins to appreciate the vast importance of the subject.

The fact, that many gentlemen of education and fortune are resorting to this primitive art, as a means of pleasure or for scientific purposes, still further shows, both the dignity of the employment, and its power of affording those simple and satisfying pleasures, which cannot be derived from mercantile or professional pursuits.

In view of such considerations, the author has been deeply impressed with the desirableness of furnishing the young farmer with a scientific knowledge of his profession. This is especially desirable, in order to give dignity and attractiveness to the employment. A thorough knowledge of the fundamental principles upon which the art is based, seems almost essential to successful practice. This necessity is yearly becoming more and more imperative.

The States, generally, have made ample provision for the education of their sons, in almost every branch of knowledge, with the exception of that, upon which the profession of the majority is based. The art on which all depend, and which the great body of the people practice, is left without any professional instruction, either public or private.

To supply, in some degree, this glaring deficiency in our popular system of education, and to call the attention of those who are interested in the prosperity of our free institutions, to the importance of having the sons of republicans well instructed in this most noble art, have been the principal inducements, for giving this work to the public in its present form. For we are fully persuaded, that Agriculture will never be held in that high estimation which it deserves to be; that it will never attain to that perfection of which it is susceptible; until it is made a regular branch of study by those who practice it as a profession; until it is incorporated into our systems of education.

But although this work is designed for students in Agriculture; it is not intended to be studied exclusively by those, who are attending at some public institution. It is designed for the farmer, at whatever stage of his education he may have arrived; for we believe that it is as true of farmers, as of any other class of men, that they are "never too old to learn ;" and that, unless they are very stupid, they generally do learn something new every day of their lives.

It has been necessary, to introduce many terms of a technical character, but none are used which have not been defined, or whose signification may not be discerned by a careful examination. We trust, therefore, that the farmer will not be deterred from reading the work, because he may find words belonging to sciences which are unknown to him. If he will not only *read* the book, but *study* it, and that too in course, we venture to assure him, that he shall be able to *understand* what is written, whether he is benefited by it or not.

In the preparation of the work, the author has consulted several writers on Agricultural Chemistry, particularly Sir H. Davy, Chaptal, Sinclair, Liebig, Daubeny, Johnston and Dana; and also, various Reports and periodical publications. The views of each writer, on many important points, have been presented, and their theories examined.

In addition to an Index, a very full Table of Contents is added. This table is intended to contain a complete analysis of the work, in the form of topics. The design of this table is, to furnish the student with the most important subjects for his attention ; and, should the work ever be so fortunate, as to be introduced as a text-book into our academies, these topics may serve the purpose of direct questions.

It is proper, in this place, for the author to acknowledge his particular obligations to Dr. Samuel L. Dana of Lowell, for the many kind suggestions which he has made from time to time, and for the important aid afforded by his late work ; although not received, until nearly the whole of this work was prepared for the press.

The author would also express his obligations to the Trustees of Phillips Academy, who have so promptly responded to the suggestion of preparing a text-book for the use of the Institution under their care; and who have afforded him many facilities for bringing the work to a close at so early a date.

With the hope that this effort to improve our system of rural economy will meet with that success which is so earnestly desired, the author would now commit these results of his studies to the better judgment of those who may be induced to read what is herein written.

A. G.

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Andover, April, 1842.

TABLE OF CONTENTS.

INTRODUCTION.

BIOLOGY OF PLANTS.

CHAPTER I.—THE VITAL PRINCIPLE.

CHAPTER II.

INFLUENCE OF THE ATMOSPHERE, WATER AND OTHER AGENTS, UPON THE VITAL PRINCIPLE, AS CONNECTED WITH THE PHENOMENA OF VEGETATION.

Sect. 1. *Agency of the atmosphere.*

Sect. 3. *Influence of the imponderable agents upon the vital functions of plants.*

Sect. 4. *Agency of man.*

CHAPTER III.

PRODUCTIONS OF THE VITAL PRINCIPLE—THEIR CHARACTER, COMPOSITION, SOURCES AND ASSIMILATION.

Sect. 1. *Character and composition of the vegetable productions.*

Sect. 2. *Definitions and descriptions.—Source and assimilation of the organic constituents of plants.*

CHAPTER VI.

IMPROVEMENT OF THE SOIL.

CHAPTER VII.

IMPROVEMENT OF THE SOIL BY MANURES AND TILLAGE.

CHAPTER IX.

HORTICULTURE.

ERRATA.

Page 68—(4) instead of "*the soil*" read "*the seed.*"
" 92—1. 4th line, for "appertures" read "apertures."
" 139—margin, for "Johnson" read "Johnston."
" 149—for paragraph "6." read "7."
" 159—margin, for "Johnson" read "Johnston."
" 168—5th paragraph, for "*Ismorphism*" read "*Isomorphism.*"
" 184—2. 2d line, for "lamella" and "granula" read "lamellar" and "granular."
" 276—III. 7th line, for "De Condolle" read "De Candolle."
" 277—2d paragraph, 1st line, for "*Macaire Princeps*" read "*Macaire Princep.*"
" 296—6. 1st line, leave out the words "*jelly*, etc."
" 303—2. 1st line, for "*Curagreen moss*" read "*Carrageen moss.*"
" 227 at star (*) for solvable read soluble

INTRODUCTION.

Agriculture is the art of cultivating the soil. It includes all those processes which are requisite for the cultivation of the various grasses, grains and fruits. The rearing and fattening of animals, and the preservation and use of their productions, are generally connected with it.

Agriculture may also be regarded as a science; in which sense, it explains the reasons for these processes, or gives rules derived from experience for the performance of each operation of the art. As a science, it is of recent date, and like all new sciences many of its principles are not yet fully settled. As an art, it is the oldest, the mother of all other arts, having been practised by the first parents and founders of the race.

Agriculture must be regarded as the most *important* art, whether we take into view the number of men it has always employed, the quantity and value of its productions, or the character of the influence which it exerts upon society.

The majority of men are farmers, and farmers constitute the bone and sinew of the state. But if we take simply the quantity and value of the *agricultural productions*, we shall find that agriculture is the *greatest pecuniary interest* of every country.

In England and Wales, according to McCulloch, the quantity of wheat is not less than 12,350,000 quarters, worth 31,000,000*l.* sterling; of oats and beans, 13,500,000 quarters, worth 17,500,000*l.* sterling; to which may be added the value of the grass lands, worth 60,000,000*l.* sterling.

According to the agricultural returns for 1839, the quantity of wheat in the United States is 91,642,957 bushels annually, worth, at one dollar per bushel, $91,642,957; of other grains, oats, rye, corn, etc. 550,299,557 bushels, worth upon an average at least fifty cents per bushel, which would amount to $275,149,778; of potatoes, 113,183,619 bushels, worth, at twenty cents per bushel, $22,636,723, giving a total value of cultivated crops of $389,429,459. But this is but a small part of all the productions. The whole agricultural produce of the country, including the domestic animals, must be worth more than twice this amount. A late writer has estimated the total value of the products of the country including manufactures, at 1200 millions of dollars annually; the manufactured products being less than 200 millions. "There is no profession," says Liebig, "which can be compared in importance with that of agriculture, for to it belongs the production of food for man and animals; on it depends the welfare and development of the whole human species, the riches of states and all commerce. There is no other profession, in which the application of correct principles is productive of more beneficial effects, or is of greater and more decided influence." Compared then with this interest, *all* others are of minor importance.

Such is the incalculable interest involved in the art, that it becomes a question of primary importance, what aid it may derive from the *physical sciences*.

It can be shown I think, in very few words, that botany, chemistry, mineralogy and geology, furnish us with many principles which may be applied to this art to render it more perfect, and more productive. The laws of nature are constant and unchanging in their action. If we can learn what these laws are, as they stand related to the vegetable kingdom, we may receive important aid from being able to control them, or to bring our efforts to coincide with their agency.

I. Mineralogy and Geology afford aid to agriculture chiefly by enabling us to determine, by the inspection of the rocks and simple minerals, the character of the soil. As all soils originate from the decay of rocks, if we know what rocks are crumbled into soil we may determine with some degree of probability its character, and what agencies are at work to benefit or injure the expected crop. If by a simple inspection of the mineral ingredients of a soil, we may determine what crop will best flourish upon it, we certainly must regard the aid not only seasonable, by preventing us from expensive experiments, but also highly valuable, by enabling us to obtain a greater quantity of productions. So great is the aid which geology renders to agriculture, that one branch of it, the origin and descriptions of soils, is called by one writer (Hitchcock), "Agricultural Geology." Geology further aids agriculture by pointing out the location of useful manures, such as vegetable matters, lime and plaster.

II. Chemistry offers greater aid by far, to agriculture than any other science, because it explains those changes which must take place in the vegetable organs, and in the soil, by which the processes of vegetation are carried forward; that is, chemistry supplies the greater number of the conditions and agencies which are requisite to the highest activity of the vital functions of plants, and hence teaches us how to obtain, with the least expense, both the largest quantity, and the best quality, of products. So great is its importance, and so far does it exceed all other branches of knowledge, in its relation to agriculture, that the terms "Agricultural Chemistry" (Davy), "Chemistry of Agriculture" (Liebig), "Chemistry applied to Agriculture" (Chaptal), have been employed as titles of the most important works, in which attempts have been made to apply the principles of science to this art.

It may be necessary, however, to point out, in a general way, some of the specific forms in which this science may be useful to agriculture, both for the sake of illustrating the general *nature* of the subject, and its *importance* to the farmer.

The influence which chemistry exerts may be seen by means of the *chemical forces* which are acting both upon dead and living matter. The principal agents, by which chemistry produces its beneficial results, are *affinity*, *heat*, *light* and *electricity*.

1. *Chemical Affinity*. This is the great agent or cause of all chemical changes on the surface of the earth. It is an attraction which one kind of matter has for matter of an opposite kind. In this respect, it differs from cohesion which acts between matter of the same kind, as between two smooth pieces of lead, and it differs from gravitation, which only acts upon matter in masses, while affinity effects changes within imperceptible distances. It tends to draw together different kinds of matter, and to continue the compound until some force acts upon it to produce decomposition. This force may be heat, light or electricity, but generally it is *affinity itself;* for the most important law of its action is, that one kind of matter does not manifest the same desire to unite with every other kind indiscriminately, but the force of affinity is different between different bodies; so that when two simple bodies are united by its force, some *third* body may have a stronger attraction for each of the constituents, or for one of them, than they have for each other, and the consequence will be that the compound will be decomposed; the *third* body will unite with one constituent of the compound, and form a new and different substance. Thus, for example, the well known substance *copperas*, is found in some soils; it is composed of sulphuric acid (*oil of vitriol*), and oxide of iron (*iron rust*), and these two bodies are held together by the force of affinity; but when carbonate of lime, *common limestone*, is scattered over such a soil the copperas is decomposed, the sulphuric acid leaves the oxide of iron, being drawn away by its stronger affinity for lime, and sulphate of lime is formed, which is commonly called *gypsum* or *plaster of Paris*.

In consequence of this *election* of one body in preference to another, the composition and decomposition of bodies are rapidly effected. In some cases two compounds are *mutually* decomposed, and two new compounds formed; hence, as the force of these affinities is well known, we may calculate their influence in the soil, and to some extent in the organs of plants. We have only to ascertain of what the soil is composed, to know what changes are going forward in it, and what decompositions and recompositions will take place, when we add earths, salts and manures to it; and hence we are furnished with the means of producing any effect that we wish, and of securing the action of the *proper agents* upon the expected crop.

But to show further the agency of affinity, it will be necessary to notice some of the laws which govern it, and the other agents which modify its action.

When bodies combine by the force of affinity, they do not generally unite in any and every quantity or proportion, but are governed by strict laws, that is, *definite quantities* of each are required to complete their union; thus water is formed by the union of 1 part by weight of hydrogen and 8 parts of oxygen; so carbonic acid (or *fixed air*) is composed of exactly 6.12 parts by weight of carbon and 16 parts of oxygen, and if the proportions of these substances are changed, some other substances will be formed, but neither water nor carbonic acid. Similar laws are observed when bodies combine by volume or measure, and these laws extend to the greater number of compounds both *organic* and *inorganic;* hence, as these *quantities* are all determined (the smallest in which any body combines being called its *equivalent* or *proportional*), we may not only explain changes in the process of vegetation, and deduce important laws which tend to satisfy the mind in its investigations, but, in a more practical way, we can determine the *quantities* of different substances which any particular soil may require, especially when one saline compound is substituted for another. Thus, for example, when salts of ammonia are applied to the soil for the purpose of obtaining the influence of the ammonia, 100 lbs. of the carbonate yields an amount of ammonia equal to 146 lbs. of the sulphate. This result has been found out by long experience, but a knowledge of chemical proportions would have predicted it.

When substances thus combine in definite proportions, the compounds, generally, bear no analogy to either of the constituents. The new substances formed are in the possession of properties entirely new, and which could not have been predicted previous to experiment; hence two simple bodies by combining in different proportions form entirely different and distinct bodies, as different as common air, the exhilarating gas, and nitric acid (*aqua fortis*), which are compounds of oxygen and nitrogen; hence it is, that the almost infinite variety of vegetable productions are formed by the different combinations of a few simple substances. If, therefore, we wish to produce a greater *quantity* of any given production, we must supply the conditions which will cause such combinations to take place. Thus, for example, where soils are destitute of animal manures, from which the nitrogen may be procured necessary to form gluten and vegetable albumen in wheat, an addition of nitrate of potash, soda or ammonia, will increase the amount of these substances, and render the grain much more valuable; an addition of 2½ per cent. of gluten has been thus produced in the same weight of wheat, which would add more than 10 per cent. to its value.

In consequence of the fact, that each substance has a definite and fixed character, we are enabled, by the aid of affinity, to decompose soils, and to compare with them the vegetable products; hence we can not only learn the reason of fertility or barrenness, but also how to remedy defects, and thus point out to the practical agriculturist the process which will secure a bountiful crop. If an analysis of the soil be made before and after the crop, we may determine what the effect of any substance is upon it. By the aid of affinity we may also analyze the vegetable productions, and learn what ingredients each species of plant requires for its most perfect growth.

The *quality* of the productions themselves is also indicated in these processes, for it is found that the same quantities of wheat will not always make the same quantity of bread. The conditions therefore on which these differences depend, we may learn from an accurate knowledge, and application of chemical principles.

Another point, of great interest to the agriculturist, is the theory of the action of manures, and it is to chemistry that he must look for the most important instructions on this subject. A knowledge of the action of saline compounds, and of alkalies, is all-important to the farmer. A continued course of cropping removes them from the soil, and the cheapest and most effectual means of restoring them is a matter of the first necessity to a perfect system of tillage.

And finally, "the source of the failure of crops when planted on the same soil for several successive years," is a subject to be investigated, and its facts explained by chemical principles. This will afford an explanation of rotation of crops, and point out many important practical rules in regard to this subject.

In these, and numerous other ways, which we have not time to specify, chemistry may afford important aid to agriculture. The other chemical forces, such as heat, light and electricity, not only modify the action of affinity, but act *directly* upon the vital functions of plants.

2. *Caloric* or *Heat* exerts an agency scarcely less important than affinity itself. It also acts according to *fixed laws*, which are known. The application of these laws to agriculture, still further illustrates the utility of chemical science, and is too obvious to need further specification in this connection.

3. *Light* is absolutely essential to vegetation, but its influ-

ence is not so immediately under the control of the agriculturist as any of the preceding agents.

4. *Electricity* even more readily yields its agency to the skill of man. The electrical character of the soil may readily be determined. It may even be changed by artificial appliances, and hence what was barren and worthless, may be rendered fruitful. But as these latter forces will receive particular attention, as to their influence on vegetation, in the body of this work, it is unnecessary to enter into any further specification of their agency.

The chemical forces above enumerated, in their influence upon vegetables themselves, are in subordination to another force, the *living power ;* and hence we must resort to *vegetable physiology* for further aid, in explaining the processes of vegetation, and in pointing out the conditions for successful practice in agriculture.

III. Botany furnishes us with principles more directly applicable to agriculture, as a science, than either of the preceding sciences. In fact, one branch of this science, *the living functions of plants*, or *Biology*, including the conditions of life, and all the near or remote influences which act upon the *vital forces*, and tend to quicken or destroy them, constitutes of itself the whole *science* of agriculture. Such a view, however, might properly bring in chemistry, as a modifying force, as well as mineralogy and geology. In a more restricted sense, botany offers the following aids:

1. It explains the structure of the various organs of plants, by which we are made acquainted with the means of introducing and disposing of the matter by which they are nourished.

3. It determines the habits of each species of plant, by which we are enabled to adapt the crop to the climate and soil.

3. It points out what plants require as the condition of their most perfect growth, and how to obtain the *best quality of their products.* It enables us also to obtain the best *kinds* or *species* of plants, to ascertain their mode of propagation,

their preservation and use, with the diseases which attack them.

Plan of the Work.

I. In accordance with the above views, the first three chapters are devoted to the *conditions* of the *life* of plants, under the general head of *Biology*, including all the agents that influence the processes of vegetation, the character, composition, source and assimilation of the *vegetable principles*.

II. The next four chapters are devoted to the composition of the rocks; origin and classification, composition and improvement of soils; with the theories of the action of manures, rotation of crops, fallow crops, and practical suggestions.

III. The closing chapter explains the processes of Horticulture, with the application of those principles which are particularly connected with this important branch of agriculture.

The object of the work, then, generally, is to explain the phenomena of vegetation, and to deduce *practical* rules for the benefit of the *practical farmer;* in order to render the modes of tillage more precise and rational, and thus to afford a stimulus to intellectual and moral improvement, by making farmers more scientific men; and in order to increase the amount of agricultural productions, by rendering the earth more fertile, and the processes of cultivation easier and more successful.

If by the application of the principles contained in this work, these results are attained, in but a *slight* degree, it is all that I can hope. I will therefore conclude these introductory observations by a calculation of the value of any *slight* improvement in this most useful art.

In England, " the average produce of wheat," says Mr. Pusey, " is stated at 26 bushels per acre; if by a better *selection of seed* we could raise this amount to 27 bushels only, (a supposition by no means unlikely), we should by this apparently small improvement have added to the nation's annual income 475,000 quarters of wheat, worth, at fifty shillings, about 1,200,000*l.* yearly, which would be equal to a capital of 24, 000,000*l.* sterling gained forever to the country by this trifling increase in the growth of one article, and that in England and Wales alone;" a quantity sufficient, we may add, to feed all her starving millions in the manufacturing districts; and if, by any means, a similar increase could be effected in her other productions, she would be able to banish forever all fear of want, which now so frequently threatens to undermine the pillars of the *throne itself.*

But while the soil of England has reached nearly the maximum of fertility, ours in this country has not. Let us then calculate the value of some *slight improvements* at home, which with the aid of science and skill, may easily be made, in a few years, with little or no expense to the country.

1. Take our wheat crop for 1839. As the number of acres is not given, we cannot decide with perfect accuracy the average per acre; but taking the estimate made for the state of Massachusetts the same year, the quantity is about 15 bushels per acre. The Middle and Western States yield a much larger quantity, I think therefore we may be safe in estimating the average at 20 bushels per acre. Then 91, 642,957 bushels annually produced, would require the cultivation of 4,582,147 acres of land. Suppose now that by the use of improved modes of culture, selection of seeds, etc. we could make our wheat lands produce, on an average, as much as those of England, 26 bushels instead of 20 to the acre, (and this certainly might be done), this increase would amount annually to 27,492,882 bushels. This would add as many dollars to the national income, and would be equal to an investment of 458,214,700 dollars!

2. Let us apply the same calculation to corn, rye, oats, etc. and as 387 millions of bushels are corn, we may estimate these products, upon an average, at 30 bushels to the acre.

There would then be 18,343,318 acres devoted to these crops. Suppose now by the application of scientific principles the same increase per acre might be effected, viz. 36 bushels instead of 30, there would be added to the quantity now obtained 110,059,908 bushels; and if we estimate the whole at 50 cents per bushel, it would add 55,029,954 dollars to the annual income of the country, equal to an invested capital of 917,165,900 dollars!

3. Apply the same calculations to the potato crop; and taking the crop in Massachusetts of 1839 for the average, at 200 bushels per acre, the 113,183,619 bushels raised in this country in 1839 would require 565,918 acres of land. Suppose now an increase of 25 bushels per acre, (an estimate far below what might be realized,) and there would be added to the present quantity of this crop, 14,647,950 bushels; which, at 20 cents per bushel, would amount to 2,929,590 dollars, equivalent to a capital of 48,826,500 dollars!

4. If now we estimate the total income to the national wealth, by this addition to the cultivated crops, it will amount to the sum of 85,452,526 dollars, equivalent to a capital of 1,424,207,100 dollars! But this sum is derived from but a few of the products of the soil. When we take into account the hay and other agricultural productions, and allow the same relative increase, the amount would be more than doubled. Thus a sum of money might easily be realized which would be sufficient to found all the colleges and institutions of learning, build all the rail-roads and canals, which the wants of the country might demand during all coming time!

Let us now confine our estimates to a narrower sphere. "Suppose that the agricultural survey," says Mr. Colman, in his Fourth Report of the Agriculture of Massachusetts, "may have been, or may have proved instrumental in inducing, upon an average, by improved cultivation, an increase of one hundred bushels of corn to every town in the Commonwealth; this, at seventy-five cents per bushel for corn, and ten dollars per ton for corn fodder, would be upwards of 28,000 dollars. Suppose it may conduce to the production of an average of one hundred tons of compost manure in each town in the Commonwealth, which must be valued at one dollar per load; this would exceed a yearly income of 60,000 dollars, to say nothing of the permanent improvement it would effect in the soil. Suppose that it may conduce to the redemption of 1000 acres of peat bog, which is now worthless, converting it into productive meadows yielding two tons of hay to the acre, and keeping up its condition; this would be little more than three acres to a town; and rating its value by its income (it cannot be estimated at less than 150 dollars per acre) this would be an increase of the property of the State, which may be safely called an actual creation of land, to the value of 150,000 dollars, and a permanent income of more than 20,000 dollars per year. Here is no extravagant calculation, to say nothing of many other forms in which the influence of the survey may be felt."

Finally, in order to obtain just views of this subject, it must be remembered, that the above improvements imply a very great intellectual and moral advancement in the agricultural community; an elevation of the popular mind, the value of which cannot be estimated by bushels of grain, by silver and gold coin, but by the purity, stability and extension of our social, civil and religious institutions; and by the increased facilities for cultivating the higher powers of man. The increase of national wealth is a desirable and laudable object of pursuit, but it is mainly from the intellectual and moral influence which an improved agriculture will exert upon society, that we can derive an adequate idea of its magnitude and importance. Imperfect as the science of agriculture now is, and imperfectly as it is represented in the following pages, the interest is so *vast*, that if any *slight* improvement is secured, I shall not deem my labor wholly lost.

BIOLOGY OF PLANTS.

CHAPTER I.

THE VITAL PRINCIPLE.

MATERIAL bodies have been divided into three kingdoms, animal, vegetable and mineral. This division is an obvious one, and is a convenient mode of classifying the phenomena which each presents to the view of the common observer.

But a more philosophical examination discloses the fact, that animals and vegetables have many points of analogy, and that they *both* differ essentially, from minerals. This difference is manifested in various ways, in the *mode* of their origin, their food, growth and dependance upon other matter, foreign to themselves. But all these different modes of existence may be traced to a peculiar power, which has been called the *vital principle;* hence a more philosophical division of natural objects, is into those which are *possessed of life*, and those which are destitute of it. The former have been called *organic*, and the latter *inorganic bodies.*

SECT. 1. *Definitions.—Proofs, Nature and Uses of the Vital Principle.*

1. BIOLOGY is the science of life. The term is derived from two Greek words, and is similar in signification to the term *Physiology.* It includes all the agencies and conditions which are essential to the existence and reproduction of living beings. The term *Biology of plants* signifies nearly the same as *vegetable physiology.* It includes that peculiar power which has been called the "*vital principle*," and its connection with those agen-

cies which in any way act upon it, or seem necessary to its development in the processes of vegetation, such as soil, food, air, water, gravity, affinity, heat, light, electricity and the agency of man.

2. "*An organized* body is one in which all the parts are mutually means and ends,"* that is, "each portion ministers to the others, and each depends upon the other," the parts make up the whole, but the existence of the whole is essential to the preservation of the parts. The *parts* are *organs*, and the *whole* is *organized*."

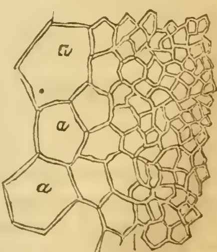
"We conceive animal life as a *vortex*, or *cycle* of moving matter, in which the form of the vortex determines the motions, and these motions again support the form of the *vortex*; the stationary parts circulate the fluids, and the fluids nourish the permanent parts."†

The same view may be taken of plants. In some vegetable products, the organs appear in a distinct form, as in the wood, leaf and blossom. In other products, as starch, gum and sugar, no such marks of organization can be distinguished. All organized bodies are the products of the living principle, whether those now possessed of life, or those that have been possessed of it, or those which have been derived from living bodies, as alcohol and vinegar.

3. *A plant* is an organized and living substance, springing from a seed or germ, which it reproduces. It is composed of an irritable, elastic matter, called *tissue*. *Tissue* is of two kinds, the *cellular* analogous to the flesh and soft parts of animals, and the *vascular*, which is similar to the bones of animals.

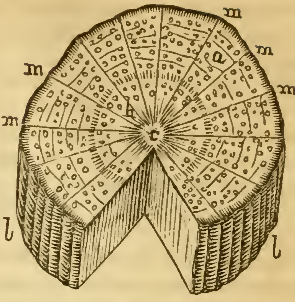
4. All plants are made up of *cells* or *vessicles*, (Fig. 1, *a a a*,) of different forms, with thin, transparent walls. When these cells press against each other, small intervals are left between them which also form tubes, called *intercellular canals*. They are the vessels in which the sap is carried up from the roots to the leaves. When these intervals increase in size, so as to exceed many times the diameter of the cells, they are called the *proper vessels*.

Fig. 1.



* Kant. † Whewell.

Fig. 2.



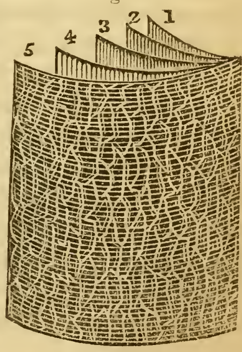
5. *Cells* are of three kinds. (1) Those of the bark and pith, of an ellipsoidal form. (2) *Elongated cells* of the *liber* and wood. These cells constitute the interior of the *bark*, and are the basis of *woody fibre.* (3) *Cells of the medullary rays.* The medullary rays pass from the pith to the bark through the wood, as in Fig. 2. *c m m m.* These cells also have *intercellular canals.*

Fig. 3.

6. *Spiral vessels* exist also in the more perfect plants. They are called *spiral* because they are fibres twisted like a cork-screw, (Fig. 3,) around an empty space. These cells occur only in wood, and are found in bundles. Each bundle contains about thirty or forty spiral tubes. A new bundle is formed every year, constituting the *annual layer of wood*, or concentric rings, as in Fig. 2. They are supposed to be *air vessels.* In grasses and grains these spiral vessels constitute the part around the interior of the hollow stem.

7. *Pores* are oblique openings or slits in the epidermis or cuticle, so small that a square inch of the epidermis of the kidney bean contains more than 300,000 pores. These pores are found chiefly on the under side of the leaf, and are the organs of *transpiration.*

Fig. 4.



8. *Epidermis* or *cuticle* is a very thin membrane which envelopes the soft parts of plants, as the leaves. It is sometimes composed, in part, of silica.

9. *Wood* is formed of bundles of spiral tubes, (See Fig. 2,) surrounded by elongated cells. The *inner bark*, (Fig. 4. 1,) is called the *liber*, and in the spring a mucilaginous matter called *cambium* is interposed between the liber and the wood; from this the first soft wood is formed, called *alburnum*, which is annually attached to the tree, while a thin layer is formed on the liber or bark, 2, 3, 4, 5.

In Fig. 2, *c* represents the pith, *b* the heart wood, *a* the alburnum, *l l m* the bark. The annual layers of wood, the medullary rays and the tubes are also represented in that figure, which is a representation of a section of the branch of a tree.

10. The process of converting the *cambium* into *alburnum* and other vegetable substances, such as sugar, gum, starch, etc. is called *assimilation* ; that of rejecting matter by the roots, *excretion* and by the leaves, *transpiration.* When substances are thrown off from the leaves, they are also said to be *exhaled ;* and when they are taken in by the leaves, they are said to be *inhaled* or *absorbed.*

Agricultural Chemistry is a term which has been generally used to denote the application of science to Agriculture. It attempts to explain the influence of earth, air and water upon plants.

That branch of the subject, which relates to the soil, as formed of simple minerals and rocks, is sometimes called *Agricultural Geology.* But as the chemical and geological agents are, in the processes of vegetation, subjected to the principle of life, it seems more appropriate to include the *vital principle ;* the conditions of its action ; the influence of other agents upon it ; its productions, with their composition and source, under the term *Biology of Plants ;* while the subject of soils and manures is placed under the term *Geology and Chemistry of Soils.*

Plants and animals differ in many respects from each other, as in their structure, in the nature of their food and in the mode and time of taking and digesting it, as well as in being governed by many different laws, but yet they both agree in possessing a *living principle.* This power is probably the same in both, and is characterized by its operations, and by its pervading every part of organized bodies. Mechanical and chemical agents are subordinated to it, in the living system, and would be wholly inefficient without it.

In the stomach of animals, for example, this power is the principal agent in elaborating the juices required to digest the food. It enables the lacteals, or small tubes which open their mouths into the alimentary canal, to select, from the general mass, whatever is fitted for nourishment, while it permits what is *injurious* or *useless* to pass by. It sends this to the heart, and gives it its never ceasing pulsations. It follows the blood to the lungs, and watches over the changes which are wrought there by the atmosphere. It returns with the blood to the heart, and propels it through every part of the system, where it assimilates it to the living body; and finally, when the living flesh and bone have served their purpose in the animal system, and the matter is no longer fitted to give strength and life to the part, it is vitality which removes it to make room for fresh particles which this same power has prepared to fill the place. Thus the *vital power* is active during every moment of animal life, in converting *dead* into *living* matter, and of removing it when it is no longer fitted to form a part of the living system. It is in the bones and muscles, in the tendons, glands and skin; it pervades the entire body, and presides over all its healthful changes and operations.

It distinguishes man from the dust on which he treads. By it he lives and moves; by it he resists the laws of nature which assail him on every side; by it he wards off the attacks of disease, or expels it when it has taken possession of his body; by it he clothes himself again with strength and beauty. It is this vital power within, that, by its constant and all-pervading energy, builds up and keeps in action that wonderful and fearful tenement which is his earthly habitation. Nor does it cease its ever active agency during all the changes and accidents of life, until his spirit departs for another world.

The *vital principle* exerts a similar influence, though not to the same extent, upon vegetables. It is this power which enables the roots to derive* nourishment from the soil, and the leaves from the air. It aids in carrying up the sap through small tubes to the leaves, where a change is wrought upon it by contact with the atmosphere. It sends the prepared nu-

* The powers of absorption and circulation of the *sap*, to a certain extent, is due to chemical and mechanical laws, but it is doubtful whether the phenomena can be wholly explained without the aid of this peculiar power.

triment down between the bark and wood, (in perennial plants,) and assimilates what is nutritious to the living tree; and, although most of the matter remains, still there is a quantity taken in which is excreted by the roots, or transpired through the leaves as unfit to enter into its composition.

This power exists in the roots, stem, leaves, juices, flowers and fruit, and presides over all the changes which are carried forward in the vegetable economy. In this case also many of the processes are, in part, purely chemical or mechanical; but these forces would be of no avail to form the *vegetable products*, if the living power or vital energy were absent, and hence we may ascribe the effect to that power, just as we do chemical changes to *affinity*, although many other agents may operate in unison with it, and modify its action.

As some chemists are disposed to doubt the existence of such a power, attempting to explain the phenomena of vegetation by *chemical* and *mechanical* forces, and particularly by what are denominated "*chemical transformations*," I will proceed to the

Proofs of its existence. The existence of such a power in plants and animals is susceptible of the same kind of proof as the power of gravitation or attraction in general. We cannot subject it to the test of the senses, as we can caloric, light and electricity. We infer its existence from the effects which are produced, and which cannot be shown to be caused by those agents which are capable of sensible demonstration.

That such a power exists in animals might be easily shown. But it is more important for our purpose to exhibit evidence of its existence in plants; in which this force differs in its *operations*, in the *conditions* requisite for its development, and in the *instruments*, by which its existence is continued.

I. *Vegetables possess the power of resisting or counteracting the laws of affinity, gravity, heat and cold.*

1. The process of the *absorption* of food, and its *elaboration* and *assimilation*, takes place in opposition to the laws of

chemical affinity; for as soon as the plant dies, this agent begins to exert its power. The elaborated juices, no longer preserved by the vital principle, exert their mutual affinities, and the whole plant in time is resolved into its original elements. This power of resisting ordinary chemical laws, and of controlling them in such a way as to make them subservient to nutrition, evinces a peculiar *vital energy.*

2. *Gravity* is constantly tending to bring the plant and its juices to the earth; but in opposition to this power the sap ascends, and the plant or tree attains in some cases an elevation of more than one hundred feet from the surface of the ground. A part of the matter which composes the tree is thus carried up in opposition to gravity. It is true that it is carried up slowly, and in small capillary tubes, in which mechanical laws operate to some extent, still this will not wholly account for the fact. It requires *vitality* to effect its ascent.

3. *Heat and cold*, two powerful agents of unorganized bodies, are resisted by vegetables within certain limits. The temperature of the juices of plants, and of their solid parts, does not rise or fall with that of the surrounding medium. The living vegetable will continue to flourish at a temperature sufficiently high to produce disorganization after it is dead, while the juices are said to circulate slowly during the cold of winter; for although the temperature of the juices is far below the freezing point, they do not always congeal unless they are taken from the tree.

This power of resisting the extremes of heat and cold is very striking in the case of some animals, which, when exposed to a temperature of 300° F. or to —80° F. retain constantly a temperature at 98 or 100° F. Vegetables possess this property in a less degree, but sufficiently to prove its existence. This effect cannot be wholly* accounted for without supposing the existence of a peculiar *vital power.*

* The heat which is found in vegetables is partly due to chemical changes. By the assimilation of the matter taken into the tree by the

II. *Excitability* in vegetables indicates the existence of a vital principle, and is one of its distinguishing properties. It is a capacity of being acted upon by natural and artificial stimulants, such as light, heat, electricity, manures and saline compounds.

1. *Light.* The stimulating influence of light upon the leaves and blossoms of vegetables, cannot have escaped the most common observation. The leaves turn their upper surfaces to the sun, and the blossoms of many plants close during the night, called the *sleep of plants*, and open only when subjected to the influence of that agent. Plants that grow in the shade are not so highly colored nor so vigorous, as those which are exposed to the light, and generally the branches and the fruit are the most vigorous on the south side of the tree. The ripe ears of grain generally lean toward the south. The branches grow in the direction of a crevice, in the wall of a cellar, through which light is admitted. These, and a great variety of phenomena prove the existence of a vital power, or *capacity* of being excited by the agency of light.

2. *Heat* exerts a powerful influence upon the functions of plants. This is seen in the germination of the seed, a certain temperature being requisite to develope the germ, and enable it to throw out roots and stalks. In the production of leaves, flowers and fruit, each development depends, to some extent, upon the degrees of heat which are applied,—hence the various means which are employed to increase or diminish the

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roots and leaves, gases and liquids are converted into solids, and by a well known law in such cases, heat is evolved; the *insensible* heat becomes *sensible;* on the same principle, as the temperature of the air diminishes, and the sap begins to freeze, a quantity of heat is *evolved.* The power of resisting heat is partly accounted for on the principle that the plant transpires a large quantity of water through the leaves, and as the heat increases, the quantity of water is increased; by the conversion of the water into vapor, a large quantity of caloric becomes insensible, the external heat is thus taken up, and the temperature of the plant remains below that of the surrounding medium.

temperature by hot-houses, inclosures, shades, etc. The vital energies of the plant are nearly suspended during the winter season. But on the return of spring, the heat which it brings with it, excites the living functions, and enables the plant to put forth its leaves; and, as the heat increases, its flowers and fruit; all of which not only prove the existence of such a principle, but also exhibit a most important property of it.

3. *Electricity* has probably a much more powerful effect upon the functions of vegetables than has been generally supposed, and tends powerfully to quicken their vital energies. Davy proved that seeds germinate sooner in water, charged with positive than with negative electricity.

4. *Artificial stimulants*, such as manures and saline compounds, and even acids and alkalies, produce effects upon the functions of vegetables which can only be accounted for on the ground that they contain a vital power which is peculiar to them, and different from the ordinary agents of dead matter.

III. *Irritability* is another property of vegetables which proves the existence of the vital principle. This property is conspicuous in the leaves of certain plants, as the *sensitive plant* and *Venus' fly trap;* but is more generally found in the stems, stamens and tendrils, as in the pea, bean and vine.

IV. *The productions* of the vegetable kingdom are decisive proofs of the existence of a vital power. Most of these productions cannot be formed by any known chemical agents.* The chemist can analyze them and show their composition to be oxygen, hydrogen, carbon and nitrogen, with a small quantity of alkalies and metallic oxides; but he has no means of

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* There is hardly an exception to the rule, that in producing *organic* substances, as they are called, the chemist must employ other organic substances which are as yet beyond his art—which, so far as we know, can only be formed *under the direction of the living principle.* In no one case can he form the substances of which animals and plants chiefly consist, out of those on which animals and plants chiefly live.—*Johnson's Lectures*, p. 190.

combining these elements so as to reproduce them. The production of woody fibre, gluten, starch, sugar, gum, resin, vegetable oils, acids and alkalies, with a few exceptions, wholly exceed the power of any known chemical or physical agent. They can be accounted for only by supposing a new and peculiar power inherent in the vegetable, which we call the power of life or the *vital principle.*

Nature of vitality. Of this we are wholly ignorant. We know it only from its effects. Like affinity and attraction, it is an ultimate power, at least, so far as science is concerned; for aught we know it is the direct power of God exerted in this particular way.

Various hypotheses, however, have been suggested to account for the phenomena of life. A few of these may properly be introduced in this connection.

1. Some, as Paracelsus, held to a spiritual being. The business of digestion was performed by the demon *Archaeus*, who had his abode in the stomach, and "who, by means of his alchemical processes, separates the nutritive from the harmful parts of our food, and makes it capable of assimilation.

2. Others, as Silvius, conceived that the vital functions were due to chemical agents, and that the power of life consists in the action of acids and alkalies, in fermentation and the like processes.

3. A third class have proposed a mechanical hypothesis, which originated about the time, and was the result of the splendid discoveries of Galileo and Newton. The phenomena of life were due to the form of the particles of matter, their motions and mutual attractions.

4. A fourth class suppose the existence of a *vital fluid*, upon which the peculiar functions of life depend. This hypothesis was proposed by Frederic Hoffman of Halle, 1694. The vital fluid was a material substance acting through the nerves, and producing the actions of all the other organs. This

is the "*Ether*, which, diffused throughout all nature, produces in plants the bud, the secretion and motion of the juices, and is separated from the blood and lodged in the brain of animals."

5. A fifth hypothesis, first proposed by Aristotle, was revived by Stahl, and refers the phenomena of life to an *animal soul*, or immaterial principle wholly distinct from a soul, as the responsible and intelligent part of man's nature. This theory has been adopted by many, but it is evidently inapplicable to plants. This objection appears to be fatal to its truth, although the *Physical School*, as those have been called who adopted this theory, are mainly right in this, that in ascribing the functions of life to a *soul*, "they mark strongly and justly the impossibility of ascribing them to any known attributes of body."*

Various attempts have also been made to define *life*, or to analyze the *idea* of it.

1. The most correct definition of life is given by Bichat, and modified by Whewell. "*Life is the system of vital functions.*" These functions are of two kinds, those which pertain to *organic life*, which are the same both in animals and vegetables, and those which belong to *animal life*, which include sensation and voluntary motion.

2. Some suppose that the *idea* of life is simple, and hence the effects of it are explained by reference to a single principle.

3. Others attempt to separate life into a *series* of vital functions, such as secretion, assimilation, absorption, etc. and hence make the idea of it complex.

But in all these attempts, there seems to be a necessity of referring the phenomena of life to some distinct force. This force has been variously denominated *organic attraction* or *vital attraction*, *organic affinity* or *vital affinity*. Professor

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* See Whewell's Philosophy of Inductive Sciences, Vol. II, in which these and other hypotheses are examined.

Müller calls it *organic assimilation*, and this seems to accord with the usage of biological writers.

But whatever name physiologists may give to this power, and whatever attempts they may make to analyze or define the idea of life, whether we study it in the separate functions of secretion, assimilation, or any other organic change, its *nature* is wholly unknown to us. We know what its effects and laws are, and can better understand them by conceiving, as their cause, a *peculiar power*, essentially distinct from the ordinary agents of dead matter, although producing both mechanical and chemical effects.

But on the supposition that such a power exists, what influence can it exert upon the theory or practice of agriculture? In answer to this inquiry, it may be observed,

1. That it is useful to have reference to the *vital power*, in the whole process of tillage. Regarding this power as the great *agent* in the process of vegetation, we may refer all the *productions* of the farm to it as a cause.

The science of tillage is a knowledge of those laws by which the vital power is governed, and of the conditions which are necessary to its activity; and practical farming consists in acting according to its laws, and in supplying those conditions which are required for its most perfect development.

I will illustrate the relation which the vital power in plants sustains to the *science* and *practice* of agriculture, by a reference to the science and practice of medicine. What is the *science* of medicine? It is a knowledge of those laws which govern the vital power, as it exists in the human species, and of those conditions which are necessary to the complete development and perfection of this power, including, of course, whatever may obstruct it in its operations. And what is the *practice* of medicine? It is mainly concerned in applying remedies to remove the obstacles to the proper action of vitality; a provision being made by our Maker in our appetites, so that we become our own physicians, in supplying most of the conditions, which are necessary to keep up the continuance and activity of this principle. But in the vegetable kingdom, nature has not given to the plant the power of making known its wants, but has left it to the farmer to learn what they are, and, if he wishes the seed or the plant to develope itself in the most perfect and useful manner, he must supply them with all those conditions, which their peculiar constitution requires. He must become acquainted not only with their natural enemies, but with their particular friends, and defend them from the attacks of the former, by surrounding them with the strong protection of the latter.

Unskilful farming, like *quackery in medicine*, has but one specific for every species of disease. It is a subject of deep regret, that *much* of the practice of medicine, and *all kinds* of quackery, are but a series of experiments upon the capabilities of the *vital power;* and, although our Creator, as if foreseeing the trial to which it would be subjected, has given it a wonderful degree of elasticity and accommodation to circumstances, although he has endowed it with an almost unconquerable power, yet when it has been long *beaten*, *bruised* and *abused*, it will cry out under its tortures, and make its sufferings known by the *emaciated form*, the *languid pulse*, and the *feeble step*.

It is scarcely less to be regretted, that *quackery in farming* is little else than experiments upon the capabilities of the vital power in seeds and plants; and although they too have a most elastic and yielding constitution, yet the neglected plant will tell you, by its stinted growth and scanty fruits, of the violence which is done to its vital energies.

2. A correct view of the vital power may serve to awaken interest, and excite admiration in view of the simple, yet beautiful laws which the Creator has established for the production and perpetuation of animal and vegetable bodies.

If we take an egg, for example, and examine it, we shall find it has a hard covering, composed of carbonate of lime, similar to chalk or marble; and a semi-fluid mass of white and yolk within, consisting mostly of a substance which chemists call *albumen.* It gives no signs of life. It hardly exhibits the marks of organization, and yet, let that same egg be subject to warmth for a few weeks, and you will find that it has been touched by the life-giving power of the Creator; that he has impressed it with a living energy, which will soon be developed in an organized, sensitive being; so peculiar in its composition, that no chemist can ever produce its like, so perfect in every part of its structure, that no mechanic can form even the smallest feather that tips the wing of the chick.

Or, if we take a seed, a kernel of corn, and examine that, we shall find it a hard, dry substance, different in composition and appearance from an egg, consisting mostly of mucilage and starch. It too is the most unlikely thing to be possessed of vitality. You may keep it a hundred years, for aught I know, and it is still the same apparently *dead* substance. But only cast it into the earth, subject it to heat and moisture, and after this long sleep of a century,* it will also show, that when it was matured upon the parent stalk, perhaps in some remote corner of the globe, the Creator treasured up and guarded in it a vital power, which will be exhibited by its taking root downward, and springing upward a living organized body, provided with organs capable of converting that which contains the contagion of death into the staff of life.

And what serves to increase our admiration, is the fact, that this power is not confined to a few seeds which are es-

* Seeds probably possess different powers of life, some preserving their *vital principle* through centuries of time, while others have an ephemeral existence under any circumstances. The reasons for this difference are unknown to us, and apparently depend upon a First Cause, over which we have therefore no control. * * I have myself raised raspberry plants from seeds found in an ancient coffin in a borough in Dorsetshire, which seeds, from the coins and other relics met with near them, may be estimated to have been sixteen or seventeen hundred years old.—*Lindley.*

pecially intended to perpetuate the species, but all alike are endowed with it, whether intended for the support of man or other animals; whether cast on rocks, into the water, by the way side, or into the fertile soil. While countless millions are annually produced, only here and there one is permitted to engage in the process of reproduction; so provident has nature been, so careful to ensure the perpetuity of the race.

3. A proper view of the vital power may serve to impress the tiller of the soil above all other men, with the most important moral lessons. Particular attention should be given to it because it is unseen and secret in its operations, and is not therefore properly considered. No credit, so to speak, is given to it. And when the farmer casts in his seed and gathers his golden harvests, he forgets the most important agent, which has been working, with unceasing energy, to fill his stores with food. Nor does he consider, while enjoying the rich rewards of his industry, the benevolent provision of his Maker in giving to every kernel of his grain the power of producing future harvests, and supplying future wants.

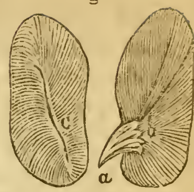
When he looks over the face of the earth and sees what an infinite variety of form, color and property, characterizes the plants which everywhere cover its surface, it may serve, at least, to humble his pride, and confound his wisdom, when he reflects that he cannot tell how a spear of grass grows, much less impart a single tint to the gorgeous coloring with which nature has adorned her covering. But he may see in every stalk of grain the workings of a hidden and mysterious power, the evidence of an all-pervading and beneficent Intelligence.

SECT. 2. *Definitions.—Conditions necessary to develope the vital principle in the seed, bulb and bud.*

1. *A seed* is a living body, capable of producing a new individual of the same species. "It is a reproductive fragment, or vital point, containing within itself all the elements of life." The seed consists of three parts, cotyledons, radicle and plumula.

2. *Cotyledons* are the seed lobes, as in the garden bean, (Fig. 5,) and are composed of matter to nourish the germ *a b*, before it can obtain food from the soil. Some seeds have no cotyledons, such as those of the mosses and ferns, and are called *acotyledonous*; other seeds have but one cotyledon, such as those of grasses, grains, etc. and are called *monocotyledonous;* others still have two, as those of leguminous plants, (the pea,) and are called *bicotyledonous.* A fourth class have more than two cotyledons, and are called *polycotyledonous*, of which the seeds of the pine and hemlock are examples.

Fig. 5.



3. *Radicle.* The radicle (Fig. 5, *b*) is that part of the embryo which shoots downwards into the earth, and forms the roots of plants.

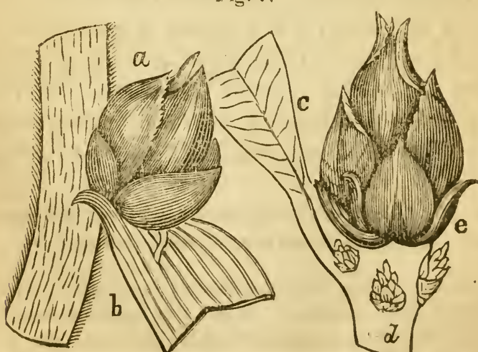
4. *Plumula.* The plumula, *a*, is that part which shoots upward into the air, and forms the stalk or stem, branches, leaves and fruit.

5. *Bulbs* are tubercles connected with the roots of plants, and contain the embryo of the future plant. The potato (Fig. 6) is a well known example of a bulb.

Fig. 6.

6. *Buds* are vital points along the stem, situated generally at the axles or angles of the leaves. The bud (Fig. 7, *a e*) is capable of forming leaf buds, flowers,

Fig. 7.



fruit or branches; or when separated from the stalk, of producing a plant, not only of the same species, but of the same variety; while seeds produce similar species, but not the same varieties.

7. *Eye* is a term applied to vital points on bulbous roots, as the potatoe, (Fig. 6, *a.*) These points are also found on the stem, (Fig. 7, *d*,) and are similar to the germ, or vital point of the seed. They are in fact the *true buds.*

8. *Chemical transformation* is a term applied to the changes which take place in compound bodies, when subjected to the influence of other substances. If the change consists simply in the new arrangement of the atoms of the compound, the change is called *catalytic;* but when the change takes place in the organs of plants, and consists in the body's yielding one ingredient, and forming by its remaining elements, or by elements obtained from the acting body, a new compound ready to pass through other similar changes, then it is called properly a *transformation;* and when a series of changes are thus produced upon water, or any other substance, the body is said to pass through *chemical transformations.*

"An organic chemical transformation is the separation of the elements of one, or of several combinations, and their reunion into two or several others, which contain the same number of elements, either grouped in another manner, or in different proportions."—*Liebig.*

The catalytic force acts by mere presence. The combination of two bodies in contact with other compounds, causes the latter to enter into a similar state. The process of fermentation will serve to illustrate the nature of this force. A small quantity of matter, in a state of fermentation, causes an indefinite quantity to enter into a similar state, as when yeast is introduced into dough.

9. *A simple substance* is one which has never been resolved into two kinds of matter, such as charcoal, silver, gold, iron, etc. The number of simple substances is fifty-five; and they are represented by letters or symbols; thus, O stands for Oxygen, H. for Hydrogen, C for Carbon, and N for Nitrogen. The quantity in which any body combines, is expressed in numbers, hydrogen being taken for unity. Only fourteen simple bodies are found in vegetables, of which the following are the names, equivalents and symbols. Hydrogen, symbol H, equivalent 1; Oxygen, Symb. O, Equiv. 8, and Nitrogen, N—14, which, in

their pure state are gaseous bodies; Carbon C—6.12, Silicon Si—22.5, Phosphorus P—15.7, and Sulphur S—16.1, which are called non-metallic combustibles, (and for which Dr. Dana has proposed the term *urets*); Potassium K—39.15, Sodium Na—23.3, Magnesium Mg—12.17, Calcium Ca—20.5, Aluminium Al—13.7, Iron Fe—28, and Manganese Mn—27.7, which are metals.

10. *Compound Bodies.* A compound body is one which is composed, or made up of two or more simple bodies. The number of compound bodies is unknown. They are represented by adding the symbols of the simple substances, which enter into their composition; thus, HO represents a compound formed by the union of oxygen and hydrogen (water). The equivalent is the sum of the equivalents of the simple bodies thus combined, $HO=1+8=9$, which is the equivalent for water.

11. When oxygen combines with any other substance, the compound is called an *alkali*, an *alkaline earth*, an *oxide* or an *acid;* thus potassa, soda and lithia are compounds of oxygen with metals, and are alkalies. Alumina, lime and magnesia are alkaline earths, and oxide of iron and of manganese are oxides. Oxygen combined with nitrogen forms nitric acid; with sulphur, silicon and carbon, sulphuric, silicic and carbonic acids.

12. When acids unite with the alkalies, alkaline earths or metallic oxides, the class of bodies formed are called *salts.* When the number of the equivalents of an acid and an alkali are equal, the salt is called *neutral.* When the alkali is in excess, the salts are called by some *sub-salts,* and when the acid is in excess they are sometimes called *super-salts.* The name of the salt terminates in *ate*, as phosphates, carbonates, nitrates. When carbon, phosphorus, silicon and sulphur unite with each other or with the metals, they are termed carburets, phosphurets, siliciurets and sulphurets.

13. An acid and an alkali unite in definite proportions, and mutually neutralize each other. Thus, 40 parts of sulphuric acid is neutralized by 48 of potash, or 20 of magnesia, or 28 of lime, or 32 of soda, or 17 of ammonia; hence these alkalies may be substituted for each other, whatever acid is used; and the same is true of acids—hence the term *equivalent*, because they may be substituted for each other, and form neutral salts.

14. Almost the entire mass of every vegetable may be resolved into two or more of four simple bodies, viz., oxygen, hydro-

gen, carbon and nitrogen. These are called the *organic constituents* of plants, because when any portion of vegetable matter is burned, it either disappears entirely, or leaves behind a small quantity of ash.

15. The ash is composed of several simple bodies, and hence these latter are called the *inorganic constituents* of plants.

Some knowledge of the organic constituents of plants, appears to be necessary for understanding the subject of this section, and, for the information of those who have not attended to elementary chemistry, a short description of them is here inserted.

1. *Oxygen* is found in the state of a gas in the atmosphere, mixed with nitrogen, and constitutes one fifth part of its volume; eight-ninths of water by weight is also oxygen gas. Beside this, the whole crust of the globe is composed of *oxydized* substances, that is, of substances combined with oxygen.

In its pure state, oxygen is a transparent gas, without color, odor or taste, and is a little heavier than the air. It unites chemically with a great number of substances. If a lighted taper is plunged into it, the brilliancy of the flame is much increased, and if heated iron be immersed in a jar of pure gas, the combustion is so intense as to melt and burn the iron. This substance is always one of the agents in all our fires and lights; hence its importance. Oxygen also is the supporter of the respiration of animals. No animal can live for any length of time without it.* It is no less essential to the existence of the vegetable kingdom.

2. *Hydrogen* is chiefly found in water, forming one-ninth part, from which it may be obtained by putting into it iron or zinc turnings and sulphuric acid. It is found in most liquids, and in all animal and vegetable bodies.

Hydrogen in its pure state exists in the form of a gas, no way distinguished in its physical properties from oxygen, with the exception of its being sixteen times lighter, and a much more powerful refractor of light. When a lighted taper is immersed in it, the hydrogen is set on fire, but the taper is extinguished. If air or oxygen gas is mixed with it, and the flame of a candle brought in contact, the mixture will explode, and the product will be water. Animals are suffocated by it, and balloons are made to ascend.

Water. One part of hydrogen and eight of oxygen, by weight,

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* See Gray's Chemistry, p. 131.

form water, (Symb. HO. eq.=9), a substance remarkable in its relation to vegetation from the ease with which it is decomposed, when subjected to the influence of the vital principle, as it passes with great facility, through several transformations in the vegetable organs.

3. *Carbon* is the most abundant substance in vegetable bodies. In its pure state, it exists as the most valued and beautiful of gems—the diamond. Common charcoal is nearly pure carbon. All kinds of coal are essentially composed of it; great quantities are also locked up in the rocks, in the form of carbonic acid, (fixed air). Common charcoal is a well known substance; it burns with a white light, but with little flame. As it constitutes from 40 to 50 per cent. of all vegetables, it has much to do in the processes of vegetation. One of its most important properties is the power of absorbing several gases, a property upon which its utility as a manure depends.

Carbonic acid. Carbon combines with oxygen, and forms carbonic acid, or fixed air. This is a gaseous, transparent substance, two and a half times heavier than common air. It is composed of one equivalent of carbon, 6.12, and two of oxygen, 16 = 22.12. Its symbol is CO^2. Carbonic acid is readily absorbed by water, to which it imparts a sour, lively taste; also a brisk, sparkling flavor to all fermented drinks, as beer. It is supposed to yield more carbon to plants than all other substances united.

4. *Nitrogen* exists in the atmosphere, of which it forms 80 per cent. It is never absent from any part of the vegetable structure, but exists in small quantities. Animals contain larger quantities of it.

Nitrogen is a transparent gas, without color, odor or taste. It is distinguished for its negative properties, for it will neither support life nor combustion, but appears to act simply as a diluent to the oxygen of the atmosphere. Its compounds, however, are among the most active and useful substances.

Nitric acid, (NO^5) commonly called *aquafortis,* is a compound of nitrogen and oxygen. It exists both in the gaseous and liquid state and is highly corrosive and active in its properties. In combination with potassa, forming nitre, and with other alkalies, it is supposed to perform important offices in vegetation.

Ammonia is well known as *hartshorn.* It is composed of nitrogen and hydrogen, (NH^3) and exists as a gas, but is rapidly absorbed by water. In its pure state it is a powerful alkali, of a caustic and burning taste, and pungent odor.*

It resembles water in the circumstance of being easily decomposed in the vegetable organs. The alkalies are tested by their turning vegetable blue colors green. Acids are tested by their imparting to the same vegetable infusions a red color.

With these definitions and descriptions the reader is prepared to attend to the subject of this section.

Germination. The development of vitality in the seed, or germ, is called the process of *germination*, by which process the embryo is extracted from its envelopes, and converted into a plant. The conditions necessary to excite the vitality of the seed are three: access to moisture, to air or oxygen gas, and to heat.

1. *Moisture.* Seeds which are fully matured and dry will retain the vital power in an inactive state for a long time, if no water is present, because this agent is necessary to facilitate the chemical changes which must take place, before it can be called into action. The first effect produced by water, is to penetrate the outer covering of the seed. The effect is purely physical, and takes place equally well in the dead and living seed. A grain of wheat, or corn, for example, deprived of its vital principle, will absorb water, and become putrescent, while one which still possesses vitality will, by imbibing moisture, develope a succession of new and living powers. The *second* effect of water, is to yield oxygen to the carbon of the germ, and form carbonic acid, which soon envelopes the seed. The decomposition of the water is effected by the vital power of the seed. The hydrogen of the water is supposed to combine with the oxygen of the air, and form water again. Few seeds, however, will complete the process of germination, when wholly immersed in water, especially if air is excluded; hence the injurious influence of a very wet soil, or a wet season, at the time of planting the seed.

* For a fuller description of the simple and compound bodies, see Gray's Chemistry.

2. *Air.* The oxygen of the air is an active agent in the process of germination. Seeds will not germinate when placed in a vacuum; in an atmosphere of carbonic acid, of nitrogen, hydrogen, or of any other gas, which does not contain oxygen. The principal substance exhaled during the process is carbonic acid. According to Liebig a small quantity of acetic acid and ammonia are also formed during the process. These gases form an atmosphere around the seed, unless it comes in contact with water. The volume of oxygen consumed is equal to that of the carbonic acid produced. The oxygen of the *air* either combines directly with the carbon,* or with the hydrogen of the decomposed water ;† hence this appears to be either a true process of decay, or of combustion, and were it not for the vital force, the seed would soon be separated into its original elements. As the oxygen of the air is absolutely essential to germination, some have supposed that the reason why seeds buried too deep, or in a stiff soil, will not germinate, is that they are not reached by it, and have inferred the importance of ascertaining the proper depth for the different kind of seeds in order to facilitate the process. On the same principle they account for the fact, that after deep tillage, plants often make their appearance, which have been cultivated upon the soil several years before. But it should be remembered that seeds thus situated are also deprived of other necessary conditions of which the absence of the oxygen of the *atmosphere* is probably the least important. Carbonic acid which is highly useful to the plant is supposed to be injurious to germination by excluding the oxy-

* "The very first act of life in a seed is to evolve carbonic acid by its carbon combining with oxygen of air, and its second act is to decompose water."—*Dana.*

† "Water is decomposed by their vital force; and its oxygen, combining with the carbon, forms carbonic acid." "Seeds have the power of decomposing water which causes the commencement of germination."—*Lindley.*

gen of the air. Hence, as the acid is often produced in the soil, in larger quantities than in the air, some have ascribed the favorable influence of lime and alkalies upon germination to the fact, that they absorb carbonic acid.

For a similar reason seeds should not be sown, or planted in direct contact with green or fermenting manures, as the process of fermentation evolves large quantities of carbonic acid, in addition to that which the seed gives out in the process of germination. This view has been given to explain a fact which farmers have learned by experience, that when green manures are placed in the hill, the corn planted upon it, will not come up so well, as when the manure is spread, and incorporated with the soil. But it is impossible to see why the carbonic acid produced in this process should not prove beneficial rather than injurious, for this acid is immediately employed to decompose the rocks, and eliminate the potash, or other alkalies, which are required to render the food soluble, and fitted to be absorbed by the plant, the instant its organs are sufficiently developed to receive it from the soil. The more probable reason for the injurious effects of green manures upon the soil is, that they impart too much nourishment, and injure the plant, by yielding more food than its organs, in this incipient state, can digest.

3. *Heat.* The third condition necessary to germination, is a proper temperature. No seed has been known to germinate at, or below the freezing point of water ; hence, seeds do not germinate during the winter, although all other conditions are supplied. The vital principle, however, is not always destroyed, but is developed on the return of spring, when the temperature has arrived at the proper degree. The requisite degree of temperature varies from 60° to 80° F. The precise temperature depends upon the nature of the seed, or plant. This accounts for the fact, that different seeds germinate at different seasons of the year ; hence the importance to the farmer of ascertaining the degree of tem-

perature requisite to the germination of the various seeds, which are cultivated upon the farm; hence, too, we see the reason and necessity of green and hot houses, to produce the requisite temperature for the germination of those seeds, which are to furnish the earlier vegetables. Heat further promotes germination, by producing those transformations which must take place in the starch and gum of the seed, and which both the external heat, and that generated within the seed duing the process, is employed in producing.

4. *Light* was formerly supposed to retard the process of germination, but according to the experiments of M. de Saussure, it takes place in the same space of time, in the light as in darkness, provided the light does not, by the heat contained in it, dry up the skins of the seed; but as this generally takes place, the burying of the seed in the soil a few inches is most favorable to the process, as the light is excluded, while heat, moisture and air are freely admitted.

The process of germination then, and the changes which take place, may be reduced to the following particulars.

1. Water penetrates the coats of the seed, causing it to swell, which facilitates the introduction of the oxygen contained in the water, and in the atmosphere to all its parts.

2. The oxygen of the water thus introduced combines chemically with the carbon which is the principal substance of the seed, forming carbonic acid; and the oxygen of the air with the hydrogen of the water, forming water. The carbonic acid acts upon the alkalies,* and these react upon the vegetable matter and convert it into vegetable food.

3. *The caloric* necessary to the process increases the chem-

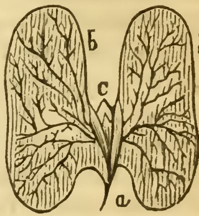
* When woody fibre or vegetable matter is brought into contact with any alkali, it enters into a process of rapid decay, and is soon converted into a substance capable of being held in solution by the water, and of entering the organs of plants. Hence the use of potash, lime, etc. in the process of germination, and during the growth of plants. Alkalies are powerful converters of vegetable matter into food.

ical action between the oxygen and the carbon, and tends to volatilize the carbonic acid which escapes in the form of gas, at the same time it excites the germ, and stimulates its development.

4. By abstracting a portion of the carbon from the mucilage and starch, of which the seed is mostly composed, a sweetish milky substance containing sugar is formed, which is the first nourishment of the embryo plant.

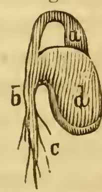
Here we may notice a very beautiful provision; the embryo rejects all nourishment from the soil, but nature has stored up in the seed itself, a most nutricious substance, fully adequate to all its wants. Fig. 8, *b d*, represents the seed lobes containing the nourishment of the embryo *c a*, with the fine tubes which convey it to the germ.

Fig. 8.



The *radicle c*, Fig. 9, gives the first indication of vitality, expanding and bursting its envelopes, and at length fixing itself in the soil. The plumula *a*, next unfolds itself, developing the rudiments of leaf, branch and trunk; finally the seminal leaves gradually drop off, and the seed is converted into a plant, capable of deriving nourishment directly from the soil, and from the atmosphere.

Fig. 9.



5. During this process, the gluten of the seed is partially changed, and forms a substance called *diastase*. This substance appears to act an important part. It has the power of transforming starch, first into gum, and then into *grape sugar*. One part of diastase will convert 2000 parts of starch into this substance. The necessity for this change, is due to the insolubility of the starch; on which account, it cannot enter into the circulation. The diastase is, therefore, formed at the point where the germ issues from the mass of food, and converts the starch into a soluble form, that it may be easily

conveyed into the organs of nutrition. As soon as this stored nutriment is exhausted, the diastase itself is transformed, and enters into the plant.

6. *Acetic acid* is also formed in the process. This is proved by the fact, that when seeds are made to germinate in powdered chalk, after a little while, *acetate of lime* may be washed out from it. This substance is very soluble in water, and the agency of the acid according to Liebig is to combine with lime and earthy substances, and convey them into the roots of plants. But since the experiments of Braconnot render it probable that *acetate of lime* is injurious to plants, this special function of the acid may well be doubted. It may aid in converting *cane sugar* or *starch* into *grape sugar*, as it is fully established that such changes take place, when these substances are brought into contact with a dilute acid. When the sprout starts up, the sugar, under the influence of light, is converted into *woody fibre.* This does not take place until the true or second leaf is expanded.

The period required for the germination of various seeds, when the requisite conditions are supplied, depends upon the *nature* of the plant, that is, upon the peculiar constitution or activity of the vital principle. The vitality of some seeds, like that of the smaller grains, peas, etc. are quickly excited; those of corn, and most of the vines require a longer period; while the stone fruits, and many of the nuts, require weeks, and even months, before they will indicate any signs of life.

The germination of seeds may be promoted by adding substances to them, either before, or after they are sown.

1. Immersing seeds in hot water has been found to promote germination. This is particularly desirable in the case of parsnips, carrots and beets, whose vital powers are not easily excited by the ordinary temperature and moisture.

2. Mr. Bowie states, that " he found the seeds of nearly all leguminous plants germinate more readily, by having water heated to 200°, or even to the boiling point of Fahrenheit's

scale, poured over them, leaving them to steep, and the water to cool for twenty-four hours," and some seeds have germinated readily, when boiled for five minutes. There is danger, however, if the water is too hot, that the vitality of most seeds will be destroyed.

3. By mixing seeds with substances which yield oxygen readily, germination is promoted. Under ordinary circumstances, oxygen is furnished from the decomposition of water, by the vital force; but when this force is languid, the supply of this agent from other sources is of the highest utility. Humboldt employed a dilute solution of chlorine, which tends to decompose the water, through its affinity for hydrogen, with which it combines, and sets the oxygen at liberty.

Mr. Otto of Berlin employed oxalic acid, which exerted such an influence upon the *vitality*, that old seeds which would otherwise die, are made to germinate readily. In all these cases, however, there is often danger of injuring the *vitality* of the seed, by yielding too much oxygen, and, with a few exceptions, the ordinary conditions are the best for the purposes of agriculture. The gardener may derive essential aid by employing these artificial methods of facilitating the germination of his seeds.

Seeds seem to be the appropriate parts of the plant from which a new individual is derived, and it appears to be the great end of all the vegetable functions to mature and fit them for this office. But although the seed is the principal means of propagation, it is not the only mode; propagation may be effected by means of *bulbs*, *buds* and *leaves*. The excitement of the vitality of bulbs and buds, depends upon the same conditions, as that of the seed, although the chemical changes are not so complicated. *The power* of propagating plants, by any other means than by seeds, depends wholly upon leaf buds, (Fig. 7,) or upon what is technically called "*eyes*;" these are found on the bulbs, and on the stem of the plant, where they are called *buds*. They are in fact rudimentary branches, containing the elements of independent existence. Some of them fall off, as in several kinds of lily, and take root, and form a new plant, while others remain attached to the stem or root.

Although all plants seem capable of being propagated by eyes, only a few are actually produced in this way. The potato and the vine are almost the only examples of the use of eyes for this purpose, unless propagation by slips, by budding and grafting, may come under this designation.

The development of vitality in the potato root is similar to that of the seed. The eye corresponds to the germ, and the bulb to the lobes of the seed. The matter necessary to supply the shoot with food, is treasured up in the bulb, just as that is in the seed lobes which nourishes the germ of the seed.

An eye from a branch of the vine being cut off with a small portion of the wood, and placed under the same conditions with the seed or bulb, will soon throw out roots and branches. The wood furnishes the nourishment required, before it can derive it from the soil; for if the eye has no wood attached to it, life will not be supported, and it will die. Other plants may be propagated in this way, but the buds and bulbs of most plants possess too little vitality to be successfully employed for this purpose. Many plants, however, may be easily propagated by small branches, called

Cuttings. When these are subjected to the proper conditions of temperature and moisture, their buds give rise to new individuals, capable of maintaining a separate existence.

Propagation by layers is the same as the above, with this difference. A *layer* is a branch bent into the earth and half cut through at the bend. When this has thrown out roots into the soil, it may be separated from the tree. The Ficus Indicus, in its natural state, propagates itself in this way.

Suckers are also employed for the propagation of plants. They are sprouts sent up from the roots of trees and shrubs, and make their appearance most frequently when the tree is cut down, because the nourishment in the roots has nothing to absorb it, and hence it forces up branches for this purpose.

In all these cases, as well as in those of budding and grafting, the principle is the same; "the vital points," are placed under fitting conditions of air, moisture and temperature, and they become converted into new individuals. Even the leaf is capable of forming buds and of continuing the species; each according to the great law of organized beings, propagates its own species; and in all cases but one the same variety of the species. The seed only preserves the same species.

Fig. 10.

The propagation of plants, by their several organs, shows the bountiful provision of nature to secure the continuance of the species. The vital points are the same, whether found in the seed, bulb, bud or leaf. The different organs, as has been shown by Goethe, are only developments of one simple germ. The leaf buds, (Fig. 10,) scales, blossoms, stamens, pistils, fruit and branches are only a development from one simple structure. The germ is converted into roots or stems, or any other organ; hence we should expect to find the vital points or eyes in all the organs, as they are, in fact, the same organ under different forms, and are easily transformed into each other. We see these transformations going on around us. In the cultivated roses, the stamens become petals. In the *potentilla nepalensis* the flowers change into branches, and the sepals, petals and stamens are converted into leaves.

Sect. 3. *Definitions.—Conditions of the Growth of Plants.*

1. *Soil.* Soil is decomposed or crumbled rock, mingled with a certain portion of animal and vegetable matter, called *humus,* or *vegetable mould.*

2. *Sub-soil.* The sub-soil lies immediately below the soil, and is mostly destitute of vegetable matter.

The parts of plants which are concerned in nutrition are the root, stem and leaves.

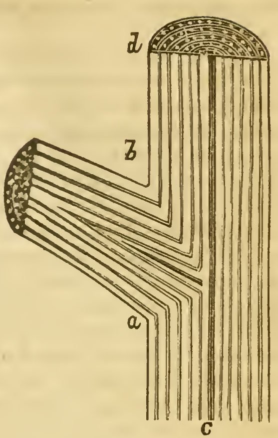
Fig. 11.

1. *Root.* The root is that part of the plant which penetrates the soil. The following are some of the different varieties of roots: *tap* roots, as in lucern and clover; *spindle* roots, as in the carrot, parsnip and beet; *branching* roots, as in most forest trees; *fibrous* roots, as in the grasses and most annual plants; *creeping* roots, as in the strawberry; *tuberous* roots, as the potato, and *bulbous* roots, as in the fleshy plants, the onion, turnip, (Fig. 11, *a*,) which are composed of regular concentric layers of vegetable matter. Roots increase in length by the addition of matter to their points. When this matter is first added it is soft, and possesses the properties of a sponge, to absorb the gaseous, or liquid bodies, which are presented to it. On this account the points *b*, are called *spongelets* or *spongioles.* It is through these, that most of the nourishment derived from the soil, is conveyed into the organs of the plant. The roots are also supposed to excrete matter into the soil, which having passed through all the transformations it is capable of in its descent from the leaves, is now rejected as unfitted to nourish the plant. The root is also supposed to have the power of selecting those substances which the wants of the plant require, as the same species will absorb unequal quantities of different substances when presented to them. But the discriminating and excretory power has been doubted, and these functions of the root are not yet fully established.

2. *Stem* or *Culm.* The stem (Fig. 12) is made up of bundles of small tubes, extending from the roots to the leaves, in which sap and air circulate. The bark contains similar tubes for the descent from the leaves of the *cambium*, or elaborated juices. The stem contains the pith *c*, which consists of tubes disposed horizontally, and forming by the medullary rays, a communication with the bark; but so far as experiments have been tried with colored solutions, the pith does not serve the purpose of circulating the sap. The tubes of the wood aid the ascent of the sap, which, in its progress upward, is subjected to certain chemical changes, and it is supposed by some that the various gaseous bodies, which are in the wood, and ascend to the leaves, are produced by transformations in the sap in its progress up-

ward. The vessels of the wood, like the roots appear to possess the power of discrimination, as to what substances they will receive. When, for example, the trunks of several trees, of the same species, are cut off above the roots, and immersed in solutions of different substances, some of these solutions will quickly ascend in the tubes, and penetrate the entire mass, while others will not be admitted at all, or very slowly, by the vessels of the tree. The functions of the stem are performed mostly by the alburnum, or sap-wood.

Fig. 12.



The branches or twigs are extensions of the trunk, as *a b*, Fig. 12.

3. *Leaves* are still further extensions of the wood, and of the bark. The fibres of the leaves are minute tubes of woody matter, connected with the wood, from which they receive the sap. The green part of the leaf is an expansion of the bark. The sap descends from this part into the bark, and thence to the root. Hence, the leaf consists of two layers of veins or fibres, covered by a thin membrane, (the epidermis,) which is an expansion of the outer bark. This membrane is filled with small apertures, for the absorption and transpiration of gaseous and liquid bodies. These pores (stomata) on the upper surface are supposed to exhale, and those on the under side of the leaf to inhale substances. They will not absorb all bodies indiscriminately, for they drink in oxygen, carbonic acid and water, but reject the nitrogen.

4. *The flower-leaves* are called *petals*, and perform the office of inhaling and exhaling various substances; but they absorb oxygen at all times, both day and night, and constantly emit carbonic acid; while, during the day, the leaves absorb carbonic acid and emit oxygen gas, and, during the night, reverse the process. The flower-leaves also exhale odoriferous particles, the nature of which, it is difficult to determine.

Although plants differ from animals in giving no signs of perception and voluntary motion, yet in their organs and processes of nutrition there is a striking analogy.

1. *The stem* and *branches* are the *frame-work* or *skeleton*, for the support of the parts which are necessary to the processes of nutrition.

2. *The roots*, in connection with the leaves, serve the purposes of mouth and stomach, absorbing and digesting those substances, which are held in solution by water or air.

3. *The common vessels* are tubes, answering to the lacteals and veins of animals. These tubes pass upward from the root through the stem, and are distributed in minute ramifications, over the surface of the leaves. Through these tubes the sap or circulating fluid ascends.

4. *The leaves* are the *lungs* which perform the office of absorbing and exhaling carbonic acid, oxygen, ammonia and water, by which the sap is prepared for its descent and assimilation.

5. *The proper vessels* are tubes corresponding to the arteries of animals, extending from the leaves through the inner layer of the bark, to the roots. In these tubes, the prepared nutriment descends, yielding, or forming in its progress, the peculiar substances which belong to the vegetable kingdom.

6. *Finally.* "The size of a plant is proportioned to the surface of the organs which are destined to convey food to it." That is, a plant obtains another mouth and stomach with every new fibre of root, and every new leaf; hence, the size depends upon the amount of the leaves and roots. If the leaves be plucked off, the plant will either die, or become stinted in growth. If the roots are diminished, a similar effect will be produced. It is on this principle, that oaks are reared by Chinese gardeners, both in Amsterdam and London, only a foot and a half high, "although their trunks, bark, leaves, branches and whole habitus evince a venerable age." As the leaves and roots are permitted to increase, they absorb a greater quantity of nourishment. This is not returned to the soil, but is employed in forming new organs.

The conditions required for the most vigorous action of the vital principle, during the growth of plants, embrace nearly the whole science of agriculture. But I shall confine myself, in this place, to *three* conditions; a proper medium and space in which to grow, proper food, and proper tillage. A general view only of these conditions can be given in this connection, a more particular consideration of them will be reserved for future sections.

I. *Proper medium and space for growth.* In the process of germination, the only conditions are air, water, and a certain temperature. But as soon as the roots and stalks make their appearance, they require mechanical support, and a medium for the action of those agents which are necessary to their perfect development. This medium is the soil and the atmosphere. The former only demands attention in this connection. There are some aquatic plants that float upon the surface of water and derive their nourishment from it, and from the atmosphere; and a large number of parasitics, as the mistletoe, which attach themselves to larger plants or trees, and even to the rocks, such as the mosses, from which they derive support and nourishment; but all vegetables, cultivated for the use of man, and other animals, require, as a necessary condition to the most vigorous action of their vital powers, that their roots should be *fixed* in the soil.

Uses of the Soil. The soil appears to serve several purposes in this respect.

1. It furnishes *support* to the plant, and prevents it from being blown about by the winds. Different plants require different kinds of soil to give the requisite stability. Wheat requires a stiff soil; corn a light one. This results, not only from the different degrees of strength in the vital power, but also from the *character* of the roots, and the *weight* which the stalk must sustain. Those roots which lie near the surface, like most of our common grains, require a stiff soil; those which penetrate deep, like most of the hoed crops, require a light soil in order to gain the requisite support; hence the importance of adapting the crop to the character of the soil, or the soil to the nature of the root.

2. The soil is the *repository of the food* of vegetables, and a *medium* of communicating it to their roots.

3. The soil facilitates the chemical changes, necessary in the preparation of the food, and of those saline compounds, which either act as a stimulus to the vital power, or are the

means of supplying some other agency necessary to the action of the vital functions.

It has been suggested, that there is produced, by the various mineral ingredients of which soils are mostly composed, an *electrical* effect, which facilitates the absorption of the food. The soil, in connection with the living plant, is a *galvanic battery*, not only acting directly upon the vital functions, but also rapidly decomposing the soil itself.

4. The soil also serves as a *sponge* to retain the requisite supply of *water*. It retains the *caloric*, and permits a free circulation of *air;* all of which it distributes according to the wants of the plant.

5. Finally, the soil serves to retain *gaseous products*, as ammonia, which it yields up as the wants of the plant require.

Such being the important agency of the soil, it is of the highest practical interest to the farmer, to ascertain its character; for all soils do not perform these functions with the same degree of perfection; hence the farmer, before he casts the seed into the earth, should inquire, whether the soil is fitted to discharge those duties, which the peculiar constitution of the expected crop requires; and he should not hope for a bountiful harvest, unless this condition of the vital power is supplied. Proper attention to the soil is one of the secrets of successful farming. It is from this belief that I have, in future chapters, devoted so large a part of the present work to its formation, composition and improvement.

II. *Food.* The second condition required for the most vigorous action of the *vital principle*, during the growth of plants, is *proper food.* We have noticed the beautiful provision of nature, by which a supply of food is stored up in the seed or bulb, for the support of the germ. This portion, however, is small, and when it is exhausted, food must be supplied from some foreign source, from the atmosphere, the water, and from the soil; or the vital power, having nothing to act upon it, and sustain it, will be destroyed. Hence proper nourishment is equally necessary to the growth and perfection of a plant, with that of an animal, and the effect of proper or improper feeding is no more visible in the one case, than in the other. The animal and the plant are alike dependent upon foreign matter, not only for their growth, but for *existence itself.* It may be stated, then, as a general law, that

All vegetables must have a supply of food, in quantity and quality, suited to their age and character.

1. *The supply* of food must be *constant.* Plants differ from animals in this respect; the latter require it at stated times, with considerable intervals between; while the former, owing to their organs of nutrition, must have a *constant* supply, at least, during the period of growth. Perennial plants, however, in cold climates, are capable of resting for several months without drawing any nourishment from the soil; and in this respect, they resemble those animals which are torpid, during the same period.

2. *The supply* of food must be *properly regulated.* If *too much* nourishment is added at any one period of growth, the organs will become clogged, or the plant will attain a rapid, but sickly growth. This is the case, when seeds are planted in fermenting or green manures, and when plants grow upon dung-hills; hence the reason for incorporating the manures *intimately* with the soil. If *too little* food is supplied, the plant will languish, and its productions will be scanty, and of an inferior quality.

The most important rule on this subject is to *graduate the nutriment*, according to the wants of the crop, *at each successive stage of its growth.* During the process of germination, no foreign matter is needed. The young plant, as soon as its leaves have become fully expanded, derives most of its matter from the atmosphere. It is during the maturing of the fruit or grain, that plants derive most nourishment from the soil. This is supposed to be partly due to the fact, that the leaves and stalks, previous to the formation of the fruit, have their organs of absorption in a most vigorous state, but, at that period, the pores are partly closed up, and the nourishment must pass in at the roots; and partly to the *kind* of nourishment which the soil alone is capable of furnishing. Hence,

(1) In the application of manures, we may derive, from the above facts, the most important practical rules; the kind and quantity depending upon the time when the crop matures its seeds. If the crop is winter rye, or any of the smaller grains, which mature their seeds in July or August, green manures should not be applied, because the process of fermentation yields abundance of carbonic acid, which powerfully stimulates and increases the stalks and leaves, but is injurious to the formation of the grain. This process will be most active when the kernel of early grains is maturing, and the appropriate nutriment, which goes to the seed, will not then be prepared in the soil; hence there will be abundance of straw, with but little grain. But if the crop ripens its seed in September, like corn and most hoed crops, green manures are far preferable, because the fermentation will be most active, when the stalks and leaves require its influence, and the nutriment, which is formed in the soil, by this process, will be ready for the formation of the grain, by the time the seed requires it.

(2) The above facts explain the reason why crops *exhaust* the soil more when permitted to mature their seeds, than when cut green; hence, crops cut for fodder, as grass, should not be left to mature their seeds, in consequence of their exhausting effects upon the manures in the soil; hence, too, the *utility* of ploughing in green crops, because food is thus taken from the atmosphere, and added to the soil.

(3) Finally, from the same principle may be inferred the utility of "soiling," that is, of keeping farm stock on green crops, during the summer season. The green crops, deriving their support mostly from the atmosphere, exhaust the soil but little, while their conversion into manure in the stables, adds

directly to the means of fertility, of securing greater abundance in future harvests.

3. *The kind* of food must be such as the *vital forces* of the plant can *assimilate;* such as its *peculiar constitution* requires. The *nature** of the food of plants has been a subject of much conjecture and controversy. Lord Bacon believed it to be *water;* Tull and Du Hamel, *pulverized earth;* Hunter, *oil* and *salt.* But the investigations of modern chemists, have thrown much light on this subject, although some things are not yet settled. It now appears, that the food of vegetables, like that of animals, consists of several substances; that it is derived from numerous sources. The principal substances regarded as food,† are carbonic acid,‡ ammonia, water, and several organic substances which form the constituents of *vegetable mould*, and alkalies, alkaline earths, metallic oxides and several salts.

The *vegetable mould*, according to the analysis of Berzelius, consists of several compounds of carbon, oxygen, hydrogen and nitrogen, called *humin*, *humic*, *crenic* and *apocrenic* acids. The humic acid has been called *geine.* These substances are combined in the soil, in part, with alkalies and oxides, and constitute the principal food which plants derive from that source.

But different species of plants require different kinds of food, or require it in different quantities. Plants which contain a large quantity of nitrogen, must be supplied with

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* The full consideration of this subject will be deferred to a future section, on the source and assimilation of the simple bodies which enter into the composition of plants.

† Nutritive matters are, correctly speaking, those substances which when presented from without, are capable of sustaining the life, and all the functions of an organism, by furnishing to the different parts of plants, the materials for the production of their peculiar constituents. —*Liebig.*

‡ For a description of these bodies, see second and third chapters.

food containing that substance, in a form in which they can assimilate it, as in ammonia, nitric acid, crenic and apocrenic acids. Some plants, as wheat, require potash and phosphates. All kinds of grasses require silicate of potash. Sea-plants require soda. And, generally, plants require different substances to enable them to develope their organs. So also wheat requires more alkalies in quantity than barley or oats. Saussure found that wheat requires different quantities at different periods of its growth. The same fact has been observed of other plants.*

The absolute necessity of supplying plants with appropriate nourishment, of nutriment derived from animal and vegetable manures, has been proved, by the most carefully conducted experiments, whatever be the particular form in which the food is presented, whether as carbonic acid, water, ammonia and saline compounds, or, in addition, as geates or humates, crenates and apocrenates. A continued course of cropping will exhaust the soil, both of vegetable matters and salts, and, unless they are restored, it will become in time, wholly barren; and in proportion as these matters are wanting, or in a state unfitted to enter the organs of plants, will the soil become sterile, its productions scanty, and of an inferior quality.

3. *Tillage.* The third general condition necessary to the growth of plants, is *proper tillage.* The object of tillage, is to break up the entire soil, and give it such a degree of fineness, as to render it permeable to atmospheric agents and water, and to incorporate the manures with the soil; thus to promote an equal and economical distribution of food to the roots of plants; to bury the seed at the proper depth; and finally, to destroy weeds, which rob the crop of food, and check its growth.

(1) *The soil should be thoroughly ploughed;* every part of it turned over and stirred at a sufficient depth to allow the roots of plants to extend themselves freely in every direction. If

* For a further notice of this subject, see third chapter.

this is not done, if the furrow is wider than the plough can turn, the parts not broken up will obstruct the roots, and prevent the free circulation of air and water. The water, settling in the creases of the furrows on the sub-soil, will form alternate wet and dry ridges, which will injure the delicate parts of the roots. When the soil is only partly broken, but a small part of it is brought to bear upon the roots, and hence the nourishment is withheld from the crop.

(2) *The soil should be deeply ploughed.* This is especially necessary for root crops, and highly useful for any crop, provided sufficient manure is added. Ten inches of tillage depth are far preferable to six inches, because the former depth will keep the soil drier, and render it capable of being cultivated much earlier. Such a depth renders the soil less subject to *drought*, in consequence of furnishing a larger stratum, possessing the properties of a sponge, to absorb the water and retain it for the wants of the plant. Such a soil will be a better retainer of heat; and will furnish a better medium for the action of chemical and other agents, which are necessary to the most vigorous growth of vegetables.

The experiments of Baron Von Vought, upon the estate of Flottbeck, Germany, fully establishes the *utility* of deep tillage. After making thousands of experiments during thirteen years, he came to the conclusion, that a tillage depth of from ten to fourteen inches was vastly preferable to a less depth. And Von Thâer estimates the value of soils, with a flat and deep mould, in the following proportions. If with a cultivated soil three inches in depth, the land is worth thirty-eight dollars per acre, that of five inches will be worth fifty-six dollars; that of eight inches will be worth sixty-two dollars, and that of eleven inches, seventy-four dollars. Each inch of mould between six and ten inches, increases the value eight per cent.

The *importance* of deep tillage may be inferred, from the fact, that some plants, as lucerne and sainfoin, are said to have penetrated the soil, to a depth of thirty feet, and that the tap roots of clover and some other plants extend to a depth of three feet or more.

(3) *The soil should be finely pulverized;* especially the surface to the depth of six inches; in order that the seed corn, grain, or potato shoot may be placed in earth finely divided, into which the tender fibres of the root may easily and quickly shoot, and air, water and heat operate with facility.

If the soil is *lumpy*, large pores or intervals will exist, across which, the delicate fibres of the roots will extend themselves, become exposed to injury, and unable to discharge their functions in a vigorous manner.

Professor Hitchcock accounts for the superior fertility of the alluvial soils of New England, on this principle. Such soils do not contain so large a quantity of vegetable matter as those less fertile, but their materials are in a much more finely divided state, and hence their fertility. This condition of vitality is liable to be disregarded by the farmer, because the expense of preparing the soil, in the first instance, is much increased, and because the time of sowing and of harvesting, are too far removed to impress the mind with its necessity and utility.

(4) *The soil should be covered at the proper depth.* The requisite depth varies according to the nature of the seed, but generally the smoother and finer the surface, the less the depth required. Grain covered one fourth of an inch in depth by finely pulverized earth, where it will feel the influence of heat, moisture and air combined, will be much more likely to germinate, the vitality will be much sooner excited, the roots will become more powerful and the stalks, leaves and fruit much more abundant.

The Baron Von Vought has made a numerous collection of plants, in which the seed was, in the one case, covered only two lines in depth, and in the other a little more than one inch and a half; and these plants show, " what a striking difference there is in the vital germ lying on the surface where roots and leaves, immediately, numerously and powerfully shoot forth from one point, and the weakened vital germ, lying at the depth of 1.680 inches, shoots forth few roots, but a *thin tube*, which rises as far as the surface, where a knot is formed whence the weakened germ pushes forth a single and sickly plant."

Some seeds require to be covered only by a bush-harrow. The seeds of grain-crops, and of some garden vegetables may be covered in this way, but hoed crops require a greater depth. The requisite depth depends also on other circumstances—the character of the soil, and its state of moisture or dryness. Hence farmers should adapt their mode of tillage to these circumstances, if they would derive the highest benefit from this part of culture.

(5) *Finally. The soil should be kept free of weeds.* The reason for this is, that the weeds exhaust the soil as much as, if not more than the crop, and especially in the dry season, abstract from the soil the moisture required for the grain. In this latter respect, weeds with large leaves and stems, will take up through their roots and transpire through their leaves, their weight of moisture in twenty-four hours. The vital functions of the crop are thus enfeebled or destroyed, while the ruthless weeds fatten upon the provisions which were designed for the rightful inhabitants of the soil. There is no doubt but that many a crop has been diminished one quarter, one third and even one half by the weeds which have been allowed to seed and spread themselves on the land.

The conditions of the growth of plants as presented in this section are very general, they will be more fully expanded in succeeding parts of the work.

These general conditions of life, however, should be impressed upon the mind of every farmer, if he would aid the vital power in the growth of his crops. He must supply his plants with the proper medium and support; with soil fitted to the nature of the plant; with food, in *kind* and *quantity*, suited to the age and wants of each species, and with proper tillage. Especially must he exterminate those natural foes, which make their appearance during the summer months, and which may easily be overcome if attacked before they have obtained a firm footing on the soil; but let him remember, that they possess a wonderful *fecundity*, and, like a certain animal, have many lives, they must, therefore, be made to die many deaths, before they can be completely exterminated.

The importance of supplying the conditions, for exciting the *vital principle* of seeds, and for its most perfect action during the growth of plants, may be illustrated by reference to the mechanic arts. In all these arts there is some agent, natural or artificial, employed as a moving power.

1. In locomotives and steamboats, the main spring of the whole movement is the expansive force of steam, when subjected to a high temperature. But steam has no power unless supplied with the appropriate conditions. If made in the open air it will not move a steamboat, though it may a feather. If simply confined in a boiler, it will manifest its power in no way unless it be to break from its confinement, and gain its freedom. A complicated apparatus must be supplied, the result of intense study, and multiplied experiment, before its power is available for any useful purpose; and finally, various other conditions must be added, before it will propel us across the land or the ocean.

2. In most cotton and woollen factories the moving force is water. This power also requires several conditions, before it can be usefully applied. The force of running water, though often very great, will not manufacture cotton and woollen cloths. If it is arrested in its progress to the ocean, its force will only be exerted upon the sides of the dam. Factories must be erected, wheels of the proper size and form must be constructed. There must be added a complicated apparatus of cards, spindles and looms, and after all this, cot-

ton or wool must be supplied, and workmen who understand the operation of the machinery, before the beautiful fabric is wrought and fitted to adorn our bodies, or to protect them from the vicissitudes of the seasons.

Steam and water are the great agents in these processes, but they are not the only agents, nor will they avail us unless the necessary conditions are supplied.

The vital power is much more wonderful and useful in its operations, than any of the agents of dead matter; but it will not exert its force without its conditions, any more than steam and water. When its conditions of activity are supplied, its productions in their variety, beauty and utility, exceed those of all other agents of the natural world. This power supplies the manufacturing arts with nearly all their raw material, and is emphatically the sustaining cause, in the hand of the Deity, of the present order of nature.

If it is important, then, that the mechanic and artizan should spend years of study and labor to supply the necessary conditions for the exertion of steam and water power, is it not vastly more important, that the farmer should carefully study, and faithfully supply the appropriate conditions for the exercise of the vital power, that he may avail himself of its more valuable and indispensable productions. What engineer would expect to run steamboats and locomotives, with nothing but fire and water? What manufacturer could hope to spin and weave by the mere force of hydrostatic pressure? Or what mechanic of any trade, would expect to produce a beautiful and useful material, without carefully attending to the conditions which are required for its production? Why, then, should the farmer expect a bountiful harvest, if he neglect to supply the conditions required for the activity of the vital power in the production of his crops?

In agriculture, as in the mechanic arts, we need the influence of example. We need some few farmers, in every portion of the country, who shall present living examples to all around, of the *possibility* and *utility* of supplying these conditions of vegetable life.

It is on this account that I would urge upon the young farmer to study this subject, to obtain a scientific knowledge of it, that he may be able to exhibit a practical application of the principles here suggested, when he settles down to the great business of life.

CHAPTER II.

INFLUENCE OF THE ATMOSPHERE, WATER AND OTHER AGENTS UPON THE VITAL PRINCIPLE AS CONNECTED WITH THE PHENOMENA OF VEGETATION.

Some of these agents have already been alluded to when treating of the *vital principle*, considered as the principal cause of vegetable productions. It is proposed now to consider more particularly the degree in which they favor or retard the process of nutrition, with the mode in which they act, in order more fully to explain the philosophy of the subject, and to point out suitable methods, to be employed by the agriculturist in the culture of his crops. These agents are the atmosphere, water, gravity, cohesion, affinity, heat, light, electricity, and the agency of man.

SECT. 1. *Agency of the Atmosphere.*

The atmosphere is that gaseous fluid which surrounds the earth, and extends to a distance of forty or forty-five miles above it. It is composed essentially of oxygen and nitrogen in the proportion of 21 parts of the former, to 79 of the latter in 100. The atmosphere also contains variable quantities of watery vapors, $\frac{1}{10000}$ part by volume of carbonic acid, a smaller quantity of ammonia, and several other gaseous compounds, such as hydrogen, nitric acids, sulphureted and carbureted hydrogen. It is also probable that odoriferous, saline, and metallic particles float in it; all of which, save the first, are found in exceedingly small quantities. The agency of the atmosphere may be studied under the following heads. Influence of its oxygen, of its nitrogen, of its ammonia, of its nitric acid, of its sulphureted hydrogen, of its carbonic acid, and its mechanical agency.

I. *Influence of the oxygen of the air in vegetation.* We have seen, that oxygen is a most important agent in the process of germination, combining with the hydrogen of the decomposed water, and with the carbon of the seed, and that carbonic acid is almost the only gaseous product evolved.

Oxygen is no less necessary to the *growth* of plants. This is proved by the fact, that when all other conditions are supplied, if the plant is deprived of oxygen it will wither and die; hence, when the roots of trees are surrounded with stagnant water, no oxygen being supplied to them, the leaves turn yellow and fall, but when fresh water is added, yielding the requisite quantity of oxygen, the tree will revive.

Oxygen acts principally upon the *roots* and *leaves* of *plants*. The mode of its action in the roots has been differently represented by different chemists. There are four theories. 1. The absorbed oxygen combines with the carbon of the plant. 2. It combines with the hydrogen of the decomposed water. 3. It is assimilated. 4. It combines with substances in the soil by which food is prepared.

First theory. The roots absorb oxygen and convert it by means of their carbon into carbonic acid. The truth of this theory is supposed to be proved by placing fresh roots deprived of their stems under a bell-glass receiver. They will diminish the quantity of air, by abstracting its oxygen, and forming carbonic acid. The volume of oxygen consumed is never greater than the bulk of their roots.

Place the roots thus saturated with oxygen in a receiver of air, and carbonic acid will be given off without altering the volume of the air ; but if they are placed in the open air, they will absorb a volume of oxygen equal to themselves, as in the first instance ; hence, the atmosphere abstracts the carbonic acid which the roots form.*

If the roots are connected with the stems and leaves, they will constantly absorb oxygen, and the quantity will amount, in time, to much more than their volume, because the carbonic acid which they form passes into the juices, ascends to the leaves, where it is decomposed by the action of light, or transpired with the water, if the plant is in the shade ; hence, they never become saturated. But these facts are equally well accounted for on other theories.

Second theory. The oxygen of the air, which is absorbed by the roots, combines with the hydrogen of the water, which the vital power decomposes, while the oxygen of the decomposed water combines with carbon and forms carbonic acid; hence, the agency of the oxygen of the air is to keep up the supply of water.

Third theory. The oxygen thus absorbed by the roots, is directly assimilated to the vegetable products, or, if any changes take place, the oxygen is neither converted into carbonic acid by combining with the carbon, nor into water by uniting with the hydrogen of the decomposed water. These changes may take place, but the theory supposes that the oxygen in some form is assimilated to the vegetable organs.

Fourth theory. It is possible, however, that neither of the above theories explain the reason of the necessity of oxygen to the roots of plants, in order to promote their growth. The oxygen of the air effects changes upon the *humus* of the soil, in preparing the food, and this may be the reason for its influence.

But whatever view is taken, the agency of oxygen upon the roots of plants, explains the reason why the earth must be

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* Chaptal.

stirred about them. The oxygen of the air is thus either brought into direct contact with all parts of them, so as to answer the conditions of some one of the above theories, or else it is thus brought into contact with the humus, and promotes its decay and conversion into vegetable food.

The leaves of plants also absorb oxygen from the atmosphere, especially during the night season, and sometimes in the shade, at the same time they transpire carbonic acid, and the volume of carbonic acid thrown off, is just equal to that of the oxygen consumed. The changes which take place in this process are also subjects of theory, although it is pretty well established that the last of the three following is the true one.

First theory. The oxygen, absorbed by the leaves, enters into combination with the carbon, formerly introduced into the sap of the plant, and there being no light to decompose the carbonic acid thus formed, it is exhaled, or given back to the atmosphere. This is precisely the change, which is supposed by some to take place in the lungs of animals, and is a true process of *respiration.* Some of the oxygen however must remain uncombined in the juices, as the amount of $\frac{1}{16}$ part of the quantity absorbed can be disengaged from the plant by means of heat.

Second theory. The oxygen which is absorbed by the leaves, enters into combination with the hydrogen of the water which the vital power decomposes, in the same manner as when introduced into the roots. So that water is decomposed by the plant, its oxygen assimilated, while at the same time, the hydrogen combines with the absorbed oxygen, and forms water. This, however, is a very doubtful theory of these changes, though a possible one.

Third theory. The oxygen thus absorbed, combines with the vegetable substances in the leaves. This appears to be a purely chemical process, as it takes place equally well in the dead, as in the living plant. If the substance of the leaves is known, "it is a matter of the greatest ease and certainty to calculate which of them, during life, should absorb most oxygen by chemical action when the influence of light is withdrawn." The oxygen in this casecombines with the volatile oils, and changes them into resins, in some cases, while in others, it unites with the constituents of nut-galls, and forms acids, or with substances containing nitrogen.

The carbonic acid in this case is derived from the sap; it enters the roots with the water, and when it arrives at the leaves it is not decomposed, but is transpired along with the water; this, of course, is purely a mechanical process, and the quantity of acid will depend on the quantity of water. The absorption of the oxygen and the emission of carbonic acid have no connection therefore with each other, or with the process of assimilation. A cotton wick, in a lamp filled with water, saturated with carbonic acid, acts precisely like a plant in the night; water and carbonic acid are sucked up, and evaporated from the wick.

The quantity of oxygen absorbed by plants depends upon their *vigor*, *degree of heat*, and the *nature of their leaves*.

1. *The more vigorous* the plant is, the greater the quantity of oxygen which it is capable of absorbing during any given period. This we should expect, because all the vital forces are more active, and hence the growth must be more rapid, and require a larger supply of the appropriate nutriment.

2. The same species of plants will absorb more oxygen at a temperature of 88° F. than at 55° or 56° F.* This quantity will therefore depend upon the season of the year and upon the climate.

3. The leaves of different plants do not consume the same quantity of oxygen gas, at the same temperature, and seasons of the year. The quantity varies from a little more than one half the bulk of the leaves, to eight times their volume.

The fleshy-leaved plants absorb the least oxygen, and re-

* Chaptal.

tain it with great force, (probably because they emit little or no carbonic acid). The various species of these plants, according to the experiments of Saussure, absorb during the summer months, from 1 to 1.7 of their bulk of oxygen ; hence, such plants will flourish on high mountains, where the air is rarified, and on arid sands.

The leaves of evergreen trees are next in order, as they absorb more oxygen than the fleshy-leaved plants, and much less than those trees which lose their leaves during the winter. The quantity in this class, varies during the months of May and June from 1.5 to four times their volume, and during the month of September from 0.86 to 3 times their volume.*

Of the herbaceous plants, those which grow on marshes and bogs, absorb but little oxygen gas. This may be due to the fact, that they are surrounded by an atmosphere of vapor, or of carbonic acid, which does not render the introduction of oxygen necessary. The quantity in such plants under similar circumstances varies from 0.7 to 2.3 times the volume of the leaves, while the leaves of herbaceous plants not aquatic, absorb from 0.66 to 5 times their volume.

The leaves of those trees which are *naked* during the winter, as the oak, maple, and most fruit trees, absorb the largest quantity of oxygen, and contain the most carbon. This seems to depend upon the nature of the substances formed in the leaf; thus the tasteless leaves of the *Agave Americana* absorb only 0.3 of their volume in the dark during twenty-four hours; those of the oak containing tannic acid, fourteen times as much ; and the balmy leaves of the *poplus alba* twenty-one times that quantity. The large quantity of oxygen, absorbed by these plants, may, also, be partly due to the fact, that they not only supply nourishment for the purposes of veg-

* Thompson's Chemistry, Organic bodies, p. 999.

etation during the summer, but store up large quantities for the use of the plant, before it can derive it from a foreign source in the spring. This process has been compared to *torpidity* in certain animals, which store up a quantity of fat in the autumn, from which they are nourished during their winter slumbers. But the analogy is very slight, while the chemical changes are quite different. The fat in the animal, appears to combine with the oxygen in the lungs, a process resembling the burning of a candle, by which the fat is slowly consumed; but the starch, which is laid up in the organs of the tree, is converted into sugar, and in the spring is assimilated. The process of assimilation is only delayed, until the leaves are put forth, while in animals, no assimilation of the stored matter takes place; it simply burns out.

The quantity of oxygen absorbed in all these cases must also depend upon the fertility of the soil, and the quantity of the gas contained in the air by which the plant is surrounded.

The other parts of plants, such as the wood, petals, and all those parts which are not green, absorb but a small quantity of this gas which is generally retained.

The action of oxygen, according to the experiments of Saussure, upon the fruit, during the progress of growth, is precisely similar to that upon the leaves. Fruits absorb oxygen during the night, and give it off during the day. But the experiments of Berard seem to indicate a different process, during the ripening of fruits; oxygen being absorbed, and carbonic acid given off, both in the sun, and in the shade. This is doubtless true; for it is found, that *green fruits*, fully grown, will not ripen in atmosphere deprived of oxygen, but will commence the process on its admission, provided they do not remain deprived of it too long. Hence fruits may be preserved through the year, by surrounding them with an atmosphere of carbonic acid, or by excluding the air. By the process of ripening, the animal matter, woody fibre, malic acid and water, are diminished, and the sugar is increased. This would be the effect of absorbing oxygen, and giving out carbonic acid. When the fruit decays, it gives out large quantities of carbonic acid. The carbon is furnished by the substance of the fruit, the oxygen from the decomposition of water; the same changes which take place in the decay of woody fibre, or any other vegetable body.

From this view it appears, that the principal agency of the oxygen of the air in the process of nutrition is,

1. According to the views of Thompson and other chemists, to combine with carbon, and form carbonic acid. This change takes place both in the soil, and in the living plant. In the soil, mostly by the fermentation of manures, or vegetable substances; and in the tree, by uniting with the carbon which has been previously introduced, forming carbonic acid; this with that contained in the soil and air, and which enters the vegetable organs in solution, is conveyed to the leaves, and decomposed by the influence of light; the carbon being retained or assimilated, and the oxygen sent out to combine with fresh portions of carbon, ready again to pass through the same process.

The oxygen which is absorbed by the leaves and roots, is, for the most part, transpired into the atmosphere; but a part is retained, and aids still farther, by its various combinations, the growth and perfection of the plant. Or,

2. According to Liebig, the oxygen of the air combines with the vegetable products, by a *purely chemical process*, and aids the plant in the formation of several vegetable bodies, while the oxygen which plants emit is derived from water and carbonic acid, which are decomposed in the process of assimilation. This is the more probable theory. But whatever view we take of it, whether the oxygen is derived from the air, or the water; whether it combines in the vegetable organs with carbon, or is directly assimilated, it appears to be an indispensable, but subordinate agent, to the *vital power*, forming, by its combinations, those compounds which this

power uses for the purposes of the vegetable economy; and yet, so controlled by it as to change the order of its affinities, and the character of the substances, of which it forms a part, in the vegetable kingdom.

Oxygen exerts an equally important agency upon soils and manures, combining with the metals, and forming oxides and acids, which, by their union, compose the soil; and effecting changes in the vegetable matter of the soil, especially converting insoluble into soluble food. This agency will be further illustrated in a future section.

II. *Influence of the Nitrogen of the Air.* All plants, in some of their organs, contain nitrogen in combination with other substances, but do not probably derive it *directly* from the atmosphere. Although nitrogen seems necessary to the process of vegetation, we do not know what agency *that which is contained in the air* exerts, unless it acts, simply, as a *diluent* to the oxygen. A small quantity of nitrogen is absorbed by the organs of plants, and given out again in an unaltered state.

III. *Ammonia of the Atmosphere.* That the atmosphere contained ammonia, in small quantities, every chemist well knew; but it was first proved, beyond a doubt, by Liebig, who has calculated its probable amount, both in the air, and in rain water. A pound of the latter contains from one quarter to one grain of this gas. Hence there would fall, on the surface of an acre, more than eighty pounds of ammonia, annually. The ammonia of the atmosphere, owing to its great solubility, is brought to the earth by every shower of rain, and hence must enter the organs of plants.

Ammonia is also found in the soil, in clays, in oxide of iron, and in several other bodies, which must have derived it from the atmosphere. Liebig and Dr. Wilbrand found it in maple sap, the juice of the birch, and of beet root. How is the atmosphere supplied with this substance? This question is easily answered by reference to changes in progress on the surface of the earth.

1. *The putrefaction* of animal substances is always attended by the revolution of ammonia, as a gaseous product. The nitrogen which animals contain, is separated, mostly, in this form.* In the decay of plants also, ammonia is given off. The quantity thus formed, is very great. "A generation of a thousand million men is renewed every thirty years, thousands of millions of animals cease to live, and are reproduced in a much shorter period."

The ammonia, thus produced, is partly thrown off into the atmosphere, and partly retained in the soil in the form of salts, or condensed in the pores of the humus, clay, water, or other ingredients of the soil. Some of it enters the roots of plants, a large portion is washed into the sea by rivers, or carried there in rains. A part of that which remains in the *atmosphere* is liable to be decomposed by thunder storms, so that but a small quantity of that which is derived from this source, exerts any agency upon vegetation.

2. When vegetable substances which contain no nitrogen decay or are oxidized in the open air, they exert a *catalytic* force upon the nitrogen of the atmosphere and the hydrogen of the plant, and ammonia is formed in considerable quantities.

In a similar way, also, when inorganic substances suffer oxidation in air or water, ammonia is formed; thus Faraday found, that when oxides were decomposed by potassium in the air, this gas was evolved; and Chevalier produced it by exposing moist iron filings to the influence of the atmosphere. The action of nitric acid on metallic oxides often produces it.

3. But the most abundant source of ammonia has been pointed out, I believe, by Daubeny. In volcanic districts immense quantities are evolved. This is formed in the interior of the volcano by means of heat and the decomposition of water, the hydrogen of which unites with the nitrogen of the air. This explanation is rendered evident by a very simple exper-

* In hot countries, the ammonia of fermenting dung heaps, is partly transformed into *nitric acid*.

iment; thus, if a current of moist air is passed over red hot charcoal, carbonic acid and ammonia are readily formed; hence it is easy to see, that the atmosphere must be constantly supplied with variable quantities of this gas.

What then is its influence in vegetation? A full consideration of this agency will be reserved to a future section. It is sufficient to remark here, that it is supposed,

1. To yield nitrogen to gluten and to vegetable albumen. It is supposed to enter the vegetable organs either in a pure state, or in the form of some of its salts, and, by various transformations, to yield its nitrogen and perhaps its hydrogen, to the formation of vegetable substances.

2. To stimulate the organs of plants and enable them to obtain a larger quantity of the substances of which they are composed. But as plants have no nerves, such stimulating effects have been doubted by many. The fact, however, that light, heat and electricity, produce effects upon the functions of vegetables, analogous to stimulants, shows that there is no good reason for doubting, that ammonia and other substances, may exert a similar influence. Liebig thinks that no such effect is produced, and accounts for the powerful influence of ammonia, on the principle of its yielding nitrogen, an essential constituent of vegetable organs. But Berzelius is of opinion, that such stimulating effects are produced, and that ammonia may act in this way.

3. But the most important action of ammonia is its influence upon the vegetable matter of the soil, and upon the *silicates*. It causes by its presence or catalytic power the decay of woody fibre, and renders insoluble *geine*, soluble, and capable of entering the roots of plants. It also acts upon the silicates and aids to form nitrates, especially *nitre*, (*nitrate of potassa*,) a salt which, as we shall show further along, exerts a powerful influence in vegetation.

IV. *Nitric Acid* (*aquafortis*) is formed in the atmosphere, by the discharge of electricity in thunder storms. The quantity has not been determined, but we know from experiment that it must be considerable. A succession of electric shocks, through common air or ammonia, is attended with the formation of nitric acid; Liebig found this acid in the rain, which fell during seventeen thunder storms, generally combined with lime and ammonia.

Nitric acid, as we have seen, p. 48, is composed of fourteen parts of nitrogen, and forty parts of oxygen. It is, therefore, capable of yielding to plants one or both of these organic constituents. Whether it can be absorbed by the leaves, and decomposed like ammonia and carbonic acid, is not yet fully settled; the fact that it readily dissolves in water, renders it probable, that its influence is confined, mostly, to the liquid state; and that, although there must be a small quantity thrown upon the leaves of plants in dew and rain, and consequently absorbed, yet it mostly enters the roots of plants, in the form of some of its salts, and is decomposed either in the stem, or in the leaves by the agency of light. (See chapter 3.)

V. *Light carbureted Hydrogen* is found also in the atmosphere in very small quantities. It is given off in the fermentation of compost heaps, and of other vegetable matter. It is found in marshes, and rises up from the bottom of ponds; coal mines also furnish it. It is a colorless, tasteless and inodorous gas, highly inflammable and explosive when mixed with air or oxygen gas, and is fatal to life. This gas is sparingly soluble in water, and must enter the organs of plants. It is composed of one equivalent of carbon and two of hydrogen, and may be represented by CH^2. Its agency in vegetation is not well known. It may yield carbon or hydrogen or both to plants.

VI. *Influence of the Carbonic Acid of the Atmosphere.* Carbonic acid is a constant ingredient of the atmosphere, but in very variable proportions; generally, less than one tenth per cent. or one thousandth part by weight, and, as the acid is more than twice as heavy as air, a very much less quantity by volume. According to Saussure only 0,000415 of the volume of the atmosphere is carbonic acid. The quantity varies according to the season, but the yearly average remains the same.

The existence of this acid in the atmosphere is easily accounted for, by the changes which are taking place on the surface of the earth.

1. Large quantities of carbonic acid are locked up in the rocks, especially in combination with lime, forming carbonate of lime, from which it is constantly liberated by *chemical changes.* By this means, also, many springs constantly emit it, and often large tracts of land throw it off from all parts of their surface.

2. In the process of *combustion* this acid is always formed, and the quantity which is thus emitted into the atmosphere, from all the fires in the world, is very great.

3. *The respiration of animals* produces it in such quantities, that the respiration of *men* alone would convert all the oxygen of the atmosphere into carbonic acid, in 303,000 years. But the quantity formed by other animals is probably greater than that formed by the human species.

4. *The decay of vegetables* is attended by the absorption of oxygen, decomposition of water, and emission of carbonic acid. This must add greatly to the whole amount.

The *quantity* of carbonic acid thrown into the atmosphere cannot be determined with perfect accuracy, although we know how much there is in the air at any one time. Bischof has estimated the quantity, evolved from springs and fissures in the ancient volcanic district of Eifel, to be 100,000 tons or about 27,000 tons of carbon annually. Were the same quantity to be sent up from 500 such spots, (fourteen millions of tons,) it would only be equal to that contained in the coal, which is yearly consumed in Great Britain. As all these causes are *constantly* operating we should suppose that the atmosphere would become deteriorated in a short time, and that the relative proportions of oxygen and carbonic acid would be changed; the latter increasing at the expense of the former. But when we examine the atmosphere, we find that there is a fixed relation between these two substances; one hundred parts of air contain twenty parts of oxygen by volume in one hundred, and from five to six $\frac{10}{1000}$ part of carbonic acid by volume or about $\frac{1}{1000}$ part by weight. So that the air, at the present day, is just as pure, as that which existed 4000 years ago, and, although billions of cubic feet of carbonic acid are thrown off into the air, and an equal volume of oxygen consumed, (one man consuming 45,000 cubic inches per day,) still, this relation is not disturbed.

How is this acid disposed of? and from what source is the oxygen derived to fill its place? for a cubic foot of oxygen gas, by uniting with carbon, so as to form carbonic acid, does not change its volume. The billions of cubic feet of oxygen extracted from the atmosphere, are replaced by the same number of billions of cubic feet of carbonic acid which immediately supply its place. There must be some cause, or causes, which exists, capable, both of removing the carbonic acid, and of replacing an equal volume of oxygen, which is removed from the air, by the processes above described. This cause is to be found, principally, in the process of vegetation.

1. *The carbonic acid of the atmosphere is absorbed and decomposed by vegetables; its carbon assimilated, and its oxygen given back to the atmosphere.*

All the green parts of plants are capable of absorbing this gas, but the property is mostly confined to the *leaves*, which possess it, quite independent of the plant itself, as they perform the function of absorbing carbonic acid, and emitting oxygen when separated from the stalk. The upper surfaces of leaves appear to have peculiar organs of absorption, as they will not perform this function when bruised. The presence of light is necessary, in order that the leaves may decompose carbonic acid. This fact was first proved by Ingenhouse, who also found, that plants emit no oxygen gas, when made to vegetate in the dark. In the light the leaves decompose the acid, assimilate the carbon and a part of the oxygen, while the remainder is yielded to the atmosphere. In the dark, the reverse takes place; the leaves absorb oxygen, and the carbonic acid is not decomposed, but is thrown out into the air; hence, as little carbon is assimilated, plants which grow in the shade, or in a cellar, are soft, spongy, pale and sickly.*

The quantity of acid, absorbed during the day, and decomposed, is greater than that given out during the night, and the quantity of oxygen emitted by day exceeds that absorbed at night; hence, the atmosphere furnishes carbonic acid to plants, and they in turn furnish oxygen to the air. Carbonic acid thus performs a similar office to vegetables which oxygen does to animals, the former purifies the juices of the vegetable, the latter the blood of the animal; hence, the animal and vegetable kingdoms contribute to each other's support. Animals absorb oxygen, and convert it into carbonic acid; vegetables absorb the acid thus formed, and give back to the air an equal volume of oxygen, necessary to support animals. Thus the equilibrium of the atmosphere is maintained, and both kingdoms flourish together.

Although an equal volume of gas, is given back to the atmosphere, when carbonic acid is decomposed by the leaves under the influence of solar light, it is not *all* oxygen, but a part of it is nitrogen. Saussure found that of 21.75 cubic inches of carbonic acid absorbed, only 14.72 inches of oxygen was given back, together with seven inches of nitrogen; part of the oxygen is thus assimilated to the plant.

2. *The quantity* of carbonic acid, thus absorbed, has been determined with some degree of certainty. In Saussure's experiments, plants absorb daily, more than their bulk, and, as this acid is composed of 6.12 parts by weight of carbon, and 16 of oxygen in 22.12, it is possible to calculate the probable amount of carbon, which is derived from this source. The

* See Chaptal, p. 81.

quantity is so great that a distinguished chemist (Liebig) has advocated the opinion, that plants derive their carbon *wholly* from the carbonic acid of the atmosphere.*

The quantity of acid thus absorbed and decomposed varies greatly in different plants, even when placed under the same circumstances. Saussure has proved that the portion depends upon the surface; hence, those plants, which have *thin leaves*, absorb more than the *fleshy-leaved* plants. The same is true, as we have seen, with regard to their power of absorbing oxygen gas.

Plants require different quantities of carbonic acid at different periods of their growth. The young plant requires but little, because its leaves are not sufficiently vigorous to absorb, and decompose it. The quantity required increases with the size of the leaves; hence, the greatest quantity is required when the leaves have obtained a mature growth, which period is near the middle of summer in most plants, and it is at this period that the greatest quantity is furnished by the fermentation of manures, and vegetable substances in the soil.

Carbonic acid has been considered prejudicial to the ripening of grain, because its presence, in large quantities, stimulates the leaves, and increases their *bulk* at the expense of the *grain*.

As plants during the summer season absorb the carbonic acid of the atmosphere, it would seem that during the winter season a much larger quantity would be found in the air, than in the summer; particularly as larger quantities are produced by combustion, and smaller quantities brought to the earth by rain. This would be the case were it not for the fact that in the tropics there is always a vigorous vegetation; the air is constantly circulating from the tropics towards the poles, and the reverse. By this constant motion the equilibrium is maintained, and there actually is a *larger* quantity of acid in the air in the summer than in the winter, because the

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* See third chapter.

causes of its production are more abundant, and some of them more active.

There are other causes which tend to abstract the carbonic acid from the atmosphere.

1. As we approach the centre of lakes or sail out upon the sea, the carbonic acid of the air gradually diminishes. This we know is due to the fact that the water absorbs it in large quantities, but as it is capable of absorbing, under the ordinary pressure, only a quantity equal to its own bulk, we should suppose that it would soon become saturated ; this, however, is not the case, and the water does not, so far as is known, return it again to the atmosphere, but disposes of it in some other way.

2. The water of rivers is constantly carrying down substances which have derived carbonic acid from the atmosphere, and it thus becomes fixed in the bottoms of lakes and seas.

3. In temperate climates, vegetable matter accumulates in the form of peat which permanently fixes large quantities of this acid.

The presence of carbonic acid is absolutely essential to vegetation. This fact has been shown by Saussure, who found that when lime was put into a glass vessel containing plants, so that the carbonic acid, both of the air and of the soil, was absorbed, they no longer continued to grow, and the leaves in a few days fell off. On examining the air, it was found to be deprived of carbonic acid ; if, however, the plant is placed in the shade, the presence of lime to absorb the carbonic acid promotes vegetation ; that is, plants grow better without the acid in the shade than with it. This process, however, cannot be continued long, as the presence of light and acid are required to continue vigorous growth.

By adding a small quantity of carbonic acid to that which already exists in the atmosphere, vegetation is promoted. When the atmosphere contains $\frac{1}{12}$ part of carbonic acid, plants vegetate much better in the sun than when placed in common air, but a larger quantity proves injurious, and when an atmosphere contains three fourths of its volume of that gas, plants will not vegetate at all, any more than they will in the pure acid. Any addition of the gas in the shade, retards rather than promotes vegetation. Sennebier has shown, that the green color of plants depends upon the absorption of carbonic acid; for this purpose light and oxygen gas must also be present.

It is a fact worthy of notice, in this connection, that carbonic acid, which is so essential to vegetation, and so grateful to be used in solution, as a drink, acts, nevertheless, as a slow poison when taken, much diluted with air, into the lungs of animals, and produces almost instant death, when introduced in a pure state.

As it is produced by ordinary combustion, every year adds many melancholy examples of its fatal power, in the case of those who are so imprudent, as to use live coals to warm sleeping apartments, which are not properly ventilated, or who use furnaces for ironing, and for culinary purposes. The acid, being heavier than the air, fills the apartment like water, and as soon as the individual dips his head into it, he is suffocated almost as soon as if plunged into water.

VII. *Mechanical agency of the atmosphere.*

1. *The pressure* of the air is of the highest importance to the vegetable kingdom. As the pressure is about 15lbs. upon every square inch of surface, its force upon the leaves and other parts of plants must be very great. It brings the oxygen, carbonic acid and ammonia into direct contact with the various organs of absorption. It also furnishes support to the external surface of plants, and enables them to withstand the pressure of the fluids within; for were the atmosphere very rare, or wholly removed, the processes within the plant would injure or burst the vessels, and decay and death would ensue.

As we ascend above the level of the ocean this pressure diminishes; hence, plants which grow on high mountains, receive less of the support above mentioned. It may be due to this circumstance, that plants with *fleshy leaves* flourish best in such regions.

2. The atmosphere not only furnishes food and support to vegetables, but it is the *medium* of communicating nourishment, and for the action of other agents. It is by the agency of the atmosphere that water is borne up from the ocean, and distributed to every part of the land, in the form of rain and dew,—that carbonic acid, ammonia, odoriferous and saline particles are conveyed to the organs of plants. Its perfect elasticity, yielding to the slightest pressure, and its constant motion, give to plants their proper exercise, without the slightest injury. It is the medium for the agency of light, heat and electrical changes, which are intimately connected with the vital functions of plants. Bearing, as it does, the clouds on its bosom, it furnishes an opportunity for some of the most sublime and beautiful phenomena of the natural world.

The iufluence of the moisture of the atmosphere will be considered in the next section.

Such are the elements of our atmosphere, and their important influence upon the vegetable kingdom. Its constitution and properties render it beautifully and wisely fitted for its indispensible agency. The manner in which its elements are combined, exhibits, in a striking light, the wisdom and benevolence of the Creator. The oxygen, nitrogen, and other gaseous bodies, of which the atmosphere is composed, seem not to be governed, as they are in other combinations, *strictly* by the laws of chemical affinity, or of mechanical mixture. Its constitution appears to be an exception to general laws, for the special benefit of the animal and vegetable kingdoms. Its elements obey *nearly* the laws of combination, which they observe when they combine in other proportions; and yet, they are so loosely united to each other, that each seems to be diffused through the other, forming independent atmospheres like a wheel within a wheel. So that any element, which the wants of the animal or the plant may require, is easily and readily abstracted.

But what should most excite our astonishment, as well as our gratitude, is the fact, that out of the six distinct and different compounds, which may be formed from the union of oxygen and nitrogen, and these two bodies compose almost the entire volume of the atmosphere, only *one* is fitted to the wants of the animal and vegetable economy. Five parts of nitrogen and one of oxygen, by weight, form the atmosphere; fourteen of nitrogen and eight of oxygen form the *exhilarating gas*, a most powerful stimulant; fourteen of nitrogen and sixteen of oxygen form a substance, the breathing of which causes almost instant death; fourteen of nitrogen and twenty-four of oxygen form a poisonous liquid; thirty-two of oxygen and fourteen of nitrogen form one of the most poisonous gases known; forty parts of oxygen and fourteen of nitrogen form the well knowu substance, *nitric acid* (aquafortis). One of these compounds, and that too the most injurious, *nitrous acid*, is formed in the atmosphere during thunder storms. If the atmosphere were suddenly changed into this acid, the whole face of nature would be almost instantly clothed with the pall of death. Why do not the elements of the atmosphere change their proportions, and produce this result? Why, but for the constant, unceasing, all-pervading agency of a wise and benevolent Intelligence.

The composition and properties of our atmosphere adapt it to a great variety of other purposes, aside from its influence upon the vegetable kingdom. Its density and elasticity are exactly fitted to the delicate structure of our lungs. Increase its density to that of water, and we should need lungs of adamant; diminish it to that of hydrogen, and our life's blood would rush out at every pore. This beautiful adaptation of our atmosphere to the animal and vegetable kingdoms, not only exhibits the skill and benevolence of Him who established and upholds the laws by which it is governed; but challenges the constant gratitude of those, who can offer no other return for having been placed under a constitution so wisely ordered for their good.

Sect. 2. *Agency of Water upon the Vital Functions of Plants.*

Water is a compound body, and may easily be decomposed by galvanism, or by adding to it sulphuric acid and iron turnings. By these processes it is shown to be composed of eight parts, by weight, of oxygen to one of hydrogen, or of one volume of the former to two of the latter; its constituents, therefore, hydrogen and oxygen, enter into the composition of vegetables in large quantities.

Water is found under three different forms, solid, liquid and gaseous.

I. *In the solid form*, as in ice and snow, water exerts considerable agency upon the living functions of plants. This it does, either by its influence upon the soil, or upon the seeds and roots of plants.

1. When water freezes in the soil, it tends to expand it, and to break down its coarser parts; when the surface thaws in the spring, the top melts first, and there is produced small appertures through which the mellowing and ameliorating influence of the atmosphere is exerted. Heavy clay lands are thus often highly benefited.

2. Snow is supposed to be beneficial to winter wheat and other crops. This it does by protecting the crop and the soil from the influence of severe cold. It forms a light, porous covering, which is an excellent *non-conductor* of heat, and hence prevents the warmth of the earth from escaping. On the same principle, by covering the young shoots of plants, it defends them from the influence of sudden varieties of temperature. When the rays of the sun fall suddenly upon a

frozen shoot, it droops and turns black; but if it be thawed gradually, it will not be injured. This is supposed to be due to the fact, that as the fluids in the vegetable organs freeze, they expand, but the air contained in adjacent vessels suffers a corresponding contraction, so that the organs are rarely burst by frost. When sudden heat is applied to the plant, in this state, the air expands more rapidly than the ice contracts, and the vessels are burst; but when the plant is thawed more slowly no such effect is produced. Hence the reason for putting frozen vegetables into water, where they will thaw gradually, in order to preserve them. Potatoes may thus be preserved frozen during the winter, and by thawing them slowly and drying rapidly they are not injured. Liebig has shown that snow contains ammonia, and this fact will serve to explain its influence upon winter wheat. It also absorbs oxygen and nitrogen, in proportions quite different from those in the atmosphere. The oxygen is only about seventeen instead of twenty-one per cent. Dana has shown that an acre receives annually fifty pounds of geine and salts in the snow.

II. The agency of water, in the *liquid form*, may be conveniently studied under the following heads. 1. Its solvent properties; 2. Its chemical agency; 3. Its mechanical agency; and, 4. As affording food.

1. *Solvent properties of water.* Water has the power of dissolving, and holding in solution a great variety of substances, animal, vegetable and mineral. It is the great *solvent* in all the operations of nature.

(1) When water passes through the soil, it dissolves out its soluble salts, such as common salt, potash, lime, nitre, etc., and conveys these substances to the roots, and thence into the organs of vegetables.

(2) Water dissolves out the soluble parts of vegetable mould and of compost manures, as fast as the chemical changes in the soil render them soluble, and fitted for the nourishment of

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plants. It thus presents these matters in a form capable of entering the organs of absorption.

(3) In a similar manner, also, by passing over animal matters, such as horns, bones, wool and animal manures, water dissolves those parts which are fitted for nutriment, as fast as formed, and, in a similar way, facilitates their introduction into the vegetable organs.

(4) Water also absorbs various gaseous compounds, such as common air, carbonic acid and ammonia; prevents them from escaping beyond the reach of the plant, and conveys them into the appropriate vessels. The quantity of carbonic acid which water is capable of absorbing is equal, at the common temperature and pressure, to its own volume.

The quantity of ammonia is much larger, amounting, according to Thompson, in some cases, to seven hundred and eighty times its bulk. These substances are brought to the earth by every shower of rain, or are absorbed as soon as formed, in the soil. The agency of water in this respect is of the highest importance in the nourishment of plants, because most of the manures which are added to soils, throw off in the process of decay, large quantities of these gases, which would be mostly lost for the purposes of nutrition, were they not instantly absorbed by the water, and retained for the use of the plant. The air which the water holds in solution, is much less, and, as we have seen, is needed in the process of germination, in a free state. Generally, all bodies which in any way constitute the food of plants, must first be dissolved in water before they can be introduced into the roots, and become a part of the living system.

2. *Chemical agency of water.* In the process of decay, putrefaction, fermentation, etc. by which food is prepared for the nourishment of plants, water is always decomposed, its hydrogen combining with the oxygen of the air, and its oxygen with the carbon of the decaying vegetable, forming carbonic acid, and other compounds, which are found in the hu-

mus, or vegetable mould of soils. It is also decomposed by the mineral constituents of the soil, and by the putrefaction of animal matters; hence we may explain the fact, that soils, by being left to rest for a few years, have their fertility restored. This is principally due to the oxygen of the water and of the air. This agency of water in the decay of vegetable matter in the soil, is somewhat remarkable, as its hydrogen combines directly with the oxygen of the air, which, with the hydrogen of the vegetable, return more water to the soil than is abstracted. In the process of germination, water, as we have seen, is decomposed, and yields its oxygen to the carbon of the germ.

3. *Mechanical agency of water.* (1) The first effect of water, in this respect, is to penetrate the outer covering of the seed, and to divide the soil so as to permit the roots of plants to extend themselves freely in every direction.

(2) The second is to convey to the roots the matter which it holds in solution. In this latter respect it is equally useful with the atmosphere itself. In passing over rocks it wears off their particles, which, with portions of the soil, and other matters, remain mechanically suspended in it. This matter is spread over the valleys by the overflowing of streams. Water is thus constantly at work in wearing down the mountains and bringing down their valuable contents upon the plains, or forming new land by the sides, or at the mouths of rivers. In this way, it becomes the greatest fertilizer known.

(3) When however it flows through soils charged with some metallic salt, like the sulphate of iron (*copperas*), it proves injurious to vegetation, and lime, or some alkali, must be added to decompose the salt, and destroy its corrosive or poisonous properties.

4. *Agency of water as nutriment.* In addition to the agency of water above described, it is used by plants as food. We know that it constitutes a large portion of the juices of plants, and, although a large portion of that which enters the roots is

transpired by the leaves, it is not all thus disposed of; the hydrogen, which is found in such abundance in vegetables, can be obtained from no other source. The vital power is able to decompose the water, and assimilate its hydrogen, while its oxygen is either combined with some other body, and rejected as excretory matter; or assimilated also to the vegetable structure. Many vegetable bodies, as woody fibre, contain carbon and the elements of water, hydrogen and oxygen, in the same relative proportions as in water, and hence water may be directly assimilated.

III. *Water in the state of vapor* ministers to the life and growth of plants, in a manner but little less effectual than in the liquid form. It boils and is converted into steam at 212° F., but the quantity of vapor thus produced is very small, compared with that which rises at all temperatures* by a process called *evaporation*, a process which is promoted by a high temperature, extent of surface, and the dryness and motion of the atmosphere.

1. By the constant evaporation of water from the surface of the ocean and the land, from the leaves of vegetables and the bodies of animals, large quantities of vapor are thrown off into the atmosphere. This quantity is found to vary with the temperature. At 50° F. the atmosphere contains about $\frac{1}{50}$ or $\frac{1}{75}$ part of its weight. At 100° F. about $\frac{1}{14}$ or $\frac{1}{20}$ part of its weight. When the temperature is diminished, it is condensed and appears in the form of vapor, or is deposited in the state of dew; hence the diminution of temperature, during the night, precipitates a quantity of moisture upon vegetables, and restores their freshness and vigor.

2. *The leaves* and *roots* have the power of absorbing the water thus thrown upon them, and, according to Liebig, after their organs of nutrition are fully matured, derive nearly

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* Major Sabine states that in the intense cold of the polar seas, not only living bodies, but the very *snow smokes*, and fills the air with vapor.

or quite enough from this source for the purposes of assimilation. The dew conveys also carbonic acid and ammonia, which we have seen are indispensable to vegetation.

3. But aside from the direct agency of water as an aliment, which we have already considered, the atmosphere performs an important agency in yielding it, at the time when its presence is most needed to modify the effects which are produced by the heat of the sun. This influence is always *beneficial,* but almost *indispensable* in dry seasons. The moisture which the air contains is conveyed, during the night, to all parts of plants, not excepting their roots, if the soil is in a proper condition to admit a circulation of air. In some countries, as Egypt, there is no rain for several months ; this defect is, in part, made up by the heavy dews which fall during the night, and tend to restore the languishing energies of the vegetable kingdom. It is owing to the direct agency of the dew upon the roots of plants, that the earth should be stirred about them, so as to keep it light, and always permeable to the air.

4. The agency of water in the form of dew presents the most striking illustration of its utility, and of its wise and beautiful adaptation to the vegetable kingdom. All bodies radiate heat into space during the night. The surface of the earth gives off more heat than it receives, and the dew is deposited. But it should be remarked, that some bodies cool much more rapidly than others; hence these bodies will first attract the particles of falling dew. Thus the grass plot is wet, while the gravel walk is dry. The dew thus seems to select the object which it would cherish, and, after having ministered to the wants of every living plant, spends its superfluity only on the naked earth or barren waste.

5. The water thus distilled into the air, is precipitated, not only in glistening dew drops, but in refreshing showers of rain. This arrangement is exceedingly beautiful, if we consider the fact, that were all the vapor condensed at once, it would not cover the earth more than five inches in depth;

but that the quantity which *annually* falls is, upon an average, thirty-three inches in depth. Hence the water, which so constantly ministers to vegetation, must be distilled five or six times during every year.

6. The process of evaporation of water produces cold, hence we may explain the reason that wet soils and clayey lands are called *cold soils.* The water which is everywhere, and constantly passing into the state of vapor, absorbs large quantities of heat, so as to produce a difference of temperature in the air of two adjacent fields. The only remedy is thorough draining.

Such is the indispensable agency of water in the vegetable economy. It is the vital fluid of plants. Upon its proper regulation depends the quantity, quality and perfection of most of the products of the earth, especially of those intended for the use of man.

Its constitution and properties, its abundance and universality, illustrate the beneficent provisions of the Creator for the preservation and sustenance of animal and vegetable life; so that here, as in all his other operations, and throughout all his works, has he shown the same skill and goodness. In the midst of this unbounded profusion, nothing is wasted, nothing is supplied without a purpose. Dead matter and material agencies are all made subservient to the demands of life.

Sect. 3. *Influence of the Imponderable Agents upon the vital Functions of Plants.*

These agents are gravity, cohesion, affinity, caloric, light and electricity. They are the great natural forces or causes of change in the material world. I shall consider them here, only in their relations to vegetation, or in their influence upon the *vital power.*

I. *Gravity.* Gravity or the attraction of gravitation is that power which all bodies, in masses, possess of attracting each other. Gravity causes a stone and all heavy bodies thrown into the air to fall to the earth. The direction of this force is towards the centre of the body; hence, all bodies falling to the earth, if not arrested at its surface, would pass on directly to its centre. This force is the cause of the pressure of the atmosphere, and of water, as well as of their motion. Water, by the force of gravity, falls from the clouds, penetrates the earth, and hurries to the ocean in streams and rivers.

The principal effect of gravity upon the functions of vegetables, is the influence it exerts upon the *direction* of their roots and branches. This influence was proved by the experiments of Mr. Knight, who fixed some seeds of the garden bean on the circumference of two wheels, the one made to revolve rapidly in a horizontal direction, and the other in a vertical direction. The beans were supplied with the requisite conditions for germination, and although the revolutions on the vertical wheel were two hundred and fifty per minute, and those on the horizontal, one hundred and fifty, the beans all grew. The roots in the vertical wheel pointed in the direction of the radii, and the stalks towards the centre where they soon met. In the horizontal wheel the centrifugal force conflicted with that of gravitation, and caused the stems or stalks to meet, in the form of a cone, over the centre of revolution, while the roots took an opposite direction. There can be no doubt, that gravity exerts considerable influence on the direction of the roots and stems of plants, and yet the reason why the seed takes root downward, and bears fruit upward, must be attributed to the *laws of vitality*.*

II. *Cohesion*. Cohesive attraction holds the parts of bodies together. This is shown when two leaden bars are scraped smooth, and pressed together; they will adhere with a force proportioned to the closeness of their contact. If that is perfect, the bar will yield in any other part as easily as at

* See Davy's Ag. Chemistry.

the point of junction. Cohesion gives to fluids a globular form as in the case of drops of water. A modification of this power, called *capillary attraction*, has considerable influence in the ascent of the sap through the *common vessels*, and in the absorption of moisture by the leaves and roots of plants. The mode, in which this is done, may be shown by placing straws in a basin of water; the water in the straws will rise much higher than that in the basin. The principle is exemplified in the wick of a lamp, the oil being drawn up by this power; also in the sponge, in sugar, and almost any body containing small tubes or pores. The force of cohesion, however, does not fully account for the ascent of the sap, although it may aid other forces in promoting its circulation.

III. *Chemical Affinity.* This power differs from gravitation and cohesion in the circumstance, that its force is always exerted between different kinds of matter.* A bar of iron, for example, is held together by cohesion, and is attracted to the earth by gravitation; but when the iron is moistened, the oxygen of the water, a very different substance from iron, unites with it and forms *iron rust.* This is effected by chemical affinity. So in the common soda powders, the tartaric acid and the soda, two different kinds of substances, combine by the force of chemical affinity. Various kinds of matter possess this attraction with different degrees of force; thus, in the soda powders, the soda is combined by affinity to carbonic acid, but the tartaric acid has a stronger attraction for the soda than the carbonic acid has, and displaces it; the liberated gas passes up through the water, and gives rise to the foam and effervescence which is so desirable and grateful, when such waters are used as a drink. This is sometimes called *elective* affinity, and gives rise to all the decompositions of matter. It will be readily perceived, that this agent must exert great influence in the phenomena of vegetation. The soil itself is composed of substances united by

* See Introduction.

chemical affinity. All the decompositions and recompositions, which take place in its mineral ingredients, and in the vegetable and animal manures are due to this power. Hence, it is active in dissolving the rocks, in forming saline compounds, and in converting manures into vegetable food. The nutriment, it is supposed by some, is held in solution in water by this same force. The sap itself is prepared for the process of assimilation, and even in this process, that is, in forming the various vegetable products, affinity exerts a constant agency, although controlled by the vital power, and made subservient to it.

Most of the substances which are added to the soil owe their utility to the changes which this power produces, especially the application of saline manures, such as lime, potash, ashes, etc. by which woody fibre is decomposed, metallic salts and acids neutralized, and their injurious properties destroyed and converted into nutriment.

So many are the changes in the process of vegetation which are purely chemical, or due to *affinity*, that some chemists have attempted to solve the mystery of life itself by this force, and hence have discarded the idea of any other vital power. It doubtless ranks next in importance to the vital principle itself, and is employed by it in nearly all the organic changes, through which the plant passes from the seed to mature growth.

IV. *Caloric.* The influence of heat in vegetation is well known, but the precise manner in which it accomplishes its beneficial or injurious effects, may need some further illustration.

Heat or caloric exists in two states, *sensible*, or the heat of temperature, and *insensible*, or in a state incapable of affecting the senses. The tendency of caloric to pass from one of these states to the other, as the forms of matter change, is one of the most important properties to consider, in its relations to vegetation. A second property is its tendency to expand all bodies, gaseous, liquid and solid; and a third is, its influence on affinity.

1. Its influence on affinity is due to its solvent and volatilizing properties. By its accumulation in bodies, it destroys *cohesion* and dissolves or melts them, and brings their particles into contact, so as to produce chemical combinations; or else it volatilizes the bodies, and removes the particles from the influence of each other's attractions. In these ways it aids or retards the decompositions and recompositions in the soil, and becomes a powerful agent in preparing the proper food of plants.

2. The effect of heat in the spring and summer is to expand the tubes or vessels of vegetables, in which the sap circulates, and also, if not too great, to render the juices more fluid. It thus promotes a more easy introduction of substances into the roots, and a more rapid circulation through the stems, branches and leaves.

But if the heat is too great, which often happens during dry seasons, when neither rain nor dew is sufficient to counteract its effects, the juices become thickened, and the vessels contracted; the plant shrivels up, and often wilts and dies. This effect would be produced more frequently, were it not,

3. For the tendency of heat to pass into an insensible state in the process of evaporation of water from the soil, and from the plant itself, and were not the plant otherwise protected, from extremes of temperature.

The fluids, which pass into the plant, are some of them converted into solids by assimilation. This process increases the temperature of the plant, by rendering *insensible* caloric *sensible*, and is a means of heat, when sufficient quantities from without are not supplied. But the greater part of the water, which enters the root, is thrown out or transpired by the leaves, and other green parts. The moisture thus thrown out upon the outer surface, by passing into vapor, absorbs the sensible and external heat. The higher the temperature, the more rapidly will the water evaporate; thus the influence of external temperature is modified, and the vital powers preserved.

*The quantity** of water thus transpired amounts, in some cases, to the weight of the plant in twenty-four hours.

The outer or upper surface of the leaf is further protected, both from the too excessive heat of the sun's rays and from the agency of water, by a thin lining of silica (*flint*), which reflects the rays. This is particularly the case with herbaceous plants or grasses; the epidermis or outer coat of the stalks and leaves being composed in part of this substance.

The temperature of the atmosphere is kept cool in the spring, by the heat which is required to convert the snow and ice into water, and the water into vapor. The process of evaporation moderates the temperature during the summer months, and the condensation of vapor in the autumn gives out heat to the air, while its conversion into ice and snow still further moderates the approach of winter.

In this way, the vegetable kingdom is preserved from the extremes of heat and cold, and from those sudden *transitions* which might otherwise injure or destroy it. See page 35.

4. During the winter, the roots of vegetables, of grasses and trees are preserved from excessive cold, by the *non-conducting* properties of snow and ice. The surface being frozen, the heat of the earth is retained, and the principle of vitality guarded from injury. The conversion of the juices of the plant into ice does not take place until a low temperature is reached. When this happens it developes its latent caloric, and the temperature of the tree from this source must be, upon an average, above that of the surrounding atmosphere.

By the variations of temperature, winds are produced, and the moisture precipitated to the earth in the form of dew and rain. By these golden showers the processes of vegetation are carried forward and enables the earth to yield her increase.

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* See Dana's Muck Manual, p. 225.

These laws, by their wise constitution and their constancy, aid in fulfilling the decree of heaven, that while the earth remains, seed time and harvest, summer and winter, cold and heat, shall not fail.

Finally. The distribution of plants over the surface of the earth is governed more by temperature than by any other circumstance. It is well known that each species of plants has its natural limit. This is particularly true of the food-bearing plants; and their agricultural limits are principally determined by temperature and moisture. The northern agricultural limits are bounded by lines passing through places of *equal summer heat* and are called *isotheral* lines.

The southern agricultural limits are bounded by similar lines of *equal winter heat*, and are called *isochimenal* lines. These lines are exceeding tortuous in their course around the earth. Thus barley, the grain which has been cultivated farthest north, has its extreme limit in the Shetland Islands, 61° N.; in the Feroe Islands, 61°—62½° N.; Lapland, 70° N.; near the White Sea, between 67° and 80° N.; in Eastern Russia, about 66° N.; and in Central Siberia, between 58° and 59° N. In North America the line is probably similar. The limit for the potato extends a little farther north. Now it is found that this line passes through places of equal summer temperature, the mean of which is from 46° to 47°.

Or if a similar examination of the northern limits of wheat be made, it will be found, that equal summer temperature is the condition of the limit. This is in latitude 64°, and the average summer temperature 57.4° F. This limit coincides with that of fruit-trees, apples, pears, and also of the oak. Other grains have similar isotheral lines which limit their northern cultivation.

If now we turn to the equatorial regions, we shall find that the limits are governed by *equal winter temperature;* for it is found that extreme heat arrests the cultivation of the grains. The temperature for germination must not exceed 120 degrees. This limit is about 20° N. latitude. The southern limit of barley is farthest north, after which wheat, then rye, and farthest south, Indian corn. Near the southern limit, as in Bengal, "Wheat, barley and oats are sown in the autumn, and harvested in March; while rice and maize are sown in May, to be harvested, as with us, in October."

It is the same condition of temperature, which limits the cultivation of the food-bearing plants on mountains. Thus, in the Alps the grains cease growing at the following heights:

Wheat at	3,400 feet,	corresponding	to latitude	64	degrees.
Oats	3,500	"	"	65	"
Rye	4,600	"	"	67	"
Barley	4,800	"	"	70	"

The above facts show the indispensable agency of heat upon the vital power, and should lead the farmer to adapt his crops to its influence, as affected by the location of the farm and the character of the soil.

V. *Light.* Light has been shown to consist of three kinds of rays. 1. *Colorific*, or those rays which give color to the various objects in nature. 2. *Calorific*, or those rays which produce heat, and are the cause of the sun's warmth. 3. *Chemical* rays, or those which produce effects upon chemical combinations. These rays are easily separated by means of a prism. Whether the effect upon vegetation results from a combination of all the rays, or is produced by one kind, is not certainly known; but the probability is that the power, in this respect, depends partly upon the *chemical rays*, and partly upon the colorific rays.

1. Light is a powerful stimulant to vegetation, changing the color of the leaves and stalks, and giving the pungent properties peculiar to each species of plant. Those vegetables which grow in the shade are always pale and sickly in growth, and insipid in taste. But let a ray of light cross the stem or leaf of such a plant, and it will turn green in that spot, and become pungent, although all other parts remain as before.

2. But the most direct agency of light is seen in the power which it gives to the leaves, to decompose the carbonic acid, and prepare the juice for the processes of assimilation. Plants which grow in the dark do not possess this power, and hence the acid remains in the juices, and the carbon is but feebly assimilated. We can see the reason why vegetation is more flourishing in the torrid zone; there is a greater quantity of light there. But each plant seems to have a constitution peculiar to itself in this respect; some being able to flourish better in the shade than others. There are some kinds of grasses, and many flowers which will flourish best in the shade, while others require to be exposed to all the light there is, and if the natural quantity is not supplied, will wilt and die.

3. The different effects produced by rays of different colors has been pointed out by Mr. Hunt. In his experiments, cress seeds were exposed in the soil to the action of the red, yellow, green and blue rays, which were transmitted through equal thicknesses of colored infusions. "After ten days, there was, under the blue fluid, a crop of cress of as bright a green as any which grew in full light, and far more abundant. The crop was scanty under the green fluid, and of a pale, yellow, unhealthy color. Under the yellow solution, only two or three plants appeared, but less pale than those under the green; while beneath the red, a few more plants came up than under the yellow, though they also were of an unhealthy color. The red and blue bottles being now mutually transferred, the crop formerly beneath the blue in a few days appeared blighted, while on the patch previously exposed to the red, some additional plants sprang up."

The necessity of light to the health and vigor of plants, is a matter of daily observation. They seem, as it were, to be endowed with a kind of instinct for it. How constantly do many leaves follow the sun in his daily course! What countless numbers of blossoms close and drop when he retires at night, and turn their faces as if eager to catch the first rays of the morning!

VI. *Electricity*. Electricity is a much more subtle agent than any which have been named; and although the mode in which it produces its effects is not so easily discovered, yet from some experiments it is rendered probable, that its action is much more direct and efficient upon the vital functions of plants, than has been commonly supposed. It seems to be widely disseminated throughout the atmosphere, the water, and the soil.

Electricity is developed by friction, and by chemical action. The former is called *common*, the latter *Voltaic* electricity, or Galvanism. Change of temperature and of form develope it, the condensation of vapor, the variations of temperature in the atmosphere, and the chemical changes, which take place in the soil, are constant sources. *The nature* of the electric fluid is unknown.

Theory. It is supposed to consist of two fluids pervading all matter; the one is called *positive* or *vitreous;* the other, *negative* or *resinous*. Each repels itself, and attracts the opposite.* Acids are generally negative, and alkalies positive; hence, the electric state of the soil may generally be known by its composition.

If a soil is wholly negative, as is the case with pure silica or sand; or wholly positive, as is the case with alumina, lime, magnesia, iron and the alkalies, *it is always wholly* barren; or when one ingredient greatly predominates, it is unfavorable to vegetation; and the object of amendments is to bring the soil to a *neutral state*.† The animal and vegetable substances in the soil produce acids and alkalies, which develope by their affinities electrical currents. The soil, being composed of different minerals, and saturated with moisture, constitutes a galvanic battery, which is constantly acting upon the functions of vegetables, and upon the rocks.

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* See Gray's Chemistry, p. 74.

† See 'Soils,' chap. 5th.

That the electrical powers thus developed must exert a constant and powerful agency upon the growth of plants, appears from the fact, that electricity is a most efficient promoter of *endosmose* or absorption. Endosmose is a term, which Mons. Dutrochet has given to a peculiar power which he discovered in experimenting upon the permeability of tissues. Its name is from the Greek, and signifies *internal impulse.* It seems to be a property possessed by all thin, membranous substances, when liquids of different densities, and electro-motive powers are placed on each side of the membrane. The following is a mechanical illustration of this curious property.

Fig. 13.

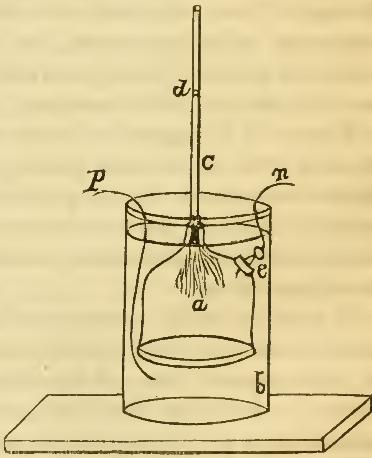

Fig. 13 represents the endosmometer. It consists of a small bell-glass receiver *a*, with a glass tube c, open at both ends, and accurately fitted to the aperture in the top c. Over the mouth of the receiver is stretched any membrane, as a fresh bladder; and a metallic substance, even and firm, with apertures punched through it, is placed upon the membrane as a support. The receiver may then be filled with sweetened water, molasses, or almost any substance denser than water, through the cork *e*. The receiver must now be placed in a vessel of water *b*, so that the water on the outside of the receiver shall be at the same height with the substance within. If now this is suffered to remain, the membrane will draw in the water, and force it up the tube, as *d.* The force thus exerted by the membrane is equal to the weight of the atmosphere, as it would, in time, raise the column of water thirty-two feet in height. If now *P*, the positive wire of a galvanic battery, is immersed in the water, and *n*, the negative wire communicate with the interior through the cork *e*, the effect will be greatly increased; and, if the wires are reversed, the liquid in the receiver may be made to flow out into the vessel of water.

According to the experiments of Dutrochet, the ascensional force in this instrument is about equal to the pressure of the atmosphere; and Mirbel found the ascensional power of the sap in a grape-vine to be the same as in this instrument. By cutting off a grape-vine, and adapting to it a glass tube filled with mercury, the outpouring of the sap will raise the mercury twenty-eight inches in the tube.

If now we examine the *spongioles* of vegetables, we shall find, that each has a bladder which stands out to absorb the nutritious particles; and that the tubes are filled with membranes, in which the endosmometric action is produced. The fluids constituting the sap are generally denser than water, a circumstance which is esssential to the action. If we suppose currents of electricity, developed in the soil, to be passing through the tubes of the vegetable, we have perhaps the most satisfactory theory of the ascent of the sap* which can be furnished. Hence it appears that one prominent object of the agriculturist is to balance the electrical forces in his soil, in order that the highest effect of this power may be produced upon his crops. There appears also to be an opposite move-

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* As the ascent of the sap may thus be accounted for on mechanical and electrical principles, it may be thought that this example is opposed to the views respecting the *vital principle*, which were presented in the first chapter. But it should be remembered, that the effect here depends upon the tissue or membrane which is a product of vitality. How can chemical laws construct the spongelets, and the membranes, which must be placed across the tubes in which the sap circulates?

ment in the endosmometer, but the liquid passes *out*, in much less quantities than it passes *in*. This movement is called *exosmose*, and may illustrate the process of transpiration, or perhaps favor the theory that plants excrete nourishment into the soil, unfitted for their own species, but capable of nourishing those of a different family.

The influence of electricity upon germination, according to Davy, is to increase the vital energies. He found that corn sprouted more rapidly in water positively electrified by the voltaic battery, than in water negatively electrified. We should suppose, from analogy, that electricity would exert a powerful influence upon the vital power of vegetables, from its known influence upon this power in minerals. In medicine, it has long since been employed as a remedy, especially to restore sensation to parts which have become deprived of feeling. Some experiments seem to prove, that continued voltaic action upon animals of microscopic dimensions, so excites and quickens the vital power, as to increase their growth a thousand fold; thus, converting animalculæ, which are too small to be seen, into visible and tangible insects. This fact has led some men even to adopt the hypothesis, that they were created by this power, that the vital and electrical powers were identically the same, and that the process of life is carried forward by a galvanic battery, consisting principally of the brain and nervous system.

As vegetables, however, are not sensitive beings, it is more difficult to trace in them, the influence of this agent; but enough is known to infer its utility, and perhaps necessity to the existence of the vegetable kingdom.

Sect. 4. *Agency of Man.*

There is but one remaining agent required for the most vigorous action of the vital principle, and that is the *farmer himself*. The vital power may exist in the seed, but it will not develope itself without his care and skill. He cannot act directly upon the functions of plants, as the other agents do, but he can modify, and, to a certain extent, control the influence of those agents. He must learn the conditions required for their beneficial action. He is the overseer, who brings together natural powers, that they may act usefully upon each other, and upon the materials which are to be manufactured. And although his agency is secondary, still it is not less necessary or beneficial, than if he could cause his crops to grow by direct power; for although the agents we have described, act with their own efficiency, and according to their own fixed laws, still they are under the control of the farmer, to a much greater extent than he supposes.

In reference to the vital power itself, we have already seen the agency of the farmer: he must supply it with certain conditions, proper food, soil, tillage, etc. before he can expect a bountiful crop. The other agents are perhaps less under his control, and it may be asked by some, of what use a description of them can be to a practical farmer. On the supposition that the atmosphere, water, light, heat and electricity, do exert all the influence which is claimed for them, are they not beyond the control of man? How can the farmer make the sun shine warmer or brighter, or the rains and dews descend in greater or less quantities? How can he control those mysterious powers of electricity and affinity, whose universal agency is witnessed by all? These inquiries arise from an erroneous idea of the case, from a false idea of the processes above named. It is because these agents are under the control of the farmer, not directly but incidentally, that they are brought forward for his consideration. Their agency is not a matter of mere science, but of practical utility, of vast importance to every man who attempts to cultivate even a garden.

1. The atmosphere and its contents. How can the farmer employ this agent? He can secure its agency by so prepar-

ing and tilling his soil that its moisture, carbonic acid, oxygen and other constituents, may circulate freely through it, to all parts of the roots. By giving to the soil a proper consistency, and by supplying it with vegetable and mineral substances, the elements of the atmosphere are made to act upon the vital functions with greater power. Thus, by giving to the soil greater absorbing power, it will feel the influence of the dews; by draining it, the injurious effects of water will be prevented, and the action of the air facilitated. If, therefore, the farmer cannot cause the rains and dews to descend at his will, he can so prepare the soil that the highest advantage may result from the influence of these agents.

2. The influence of heat. How can this agent be applied by the farmer? Simply by adding to the soil, mineral or vegetable substances, which will give it the power of absorbing and retaining the heat of the sun, or which will, by their combinations, produce heat in the soil. By the fermentation of manures, great quantities of heat are given out; hence, if the soil is naturally cold, manures should be applied before they are fermented, and incorporated with the soil that the heat may be equally distributed. By increasing the fertility of the soil, its power of retaining heat will be increased.

3. Electricity. How is the influence of this agent controlled by the farmer? If a soil is acid, that is, in a state of negative electricity, it is wholly barren; if a soil is alkaline, that is, in a positive state of electricity, it is also barren; but when its acids are neutralized by its alkalies, then it is in a state favorable to fertility, and the more completely the electro-powers of the soil are balanced, the more fertile will the soil become. Now, by analysis, the electrical state of the soil can be determined, and the substance applied which will restore the equilibrium of the electric forces. From the analysis of soils of different degrees of fertility, it is surprising to notice how narrow the limits are, between absolute barrenness and a high state of fertility. One soil, for example,

which is wholly barren, may have its fertility restored by the addition of one per cent. of lime, or even a few bushels to the acre. Another, which is acid, and therefore unfavorable to vegetation, may by the addition of a single grain in a hundred of some alkali, be made to yield forty, fifty, or a hundred fold.

Many a farm has remained for years barren, because its electrical forces were not properly balanced, while the addition of some well-known substance, perhaps in the proportion of not more than one grain in a million, would restore it to fertility. It is said by certain medical practitioners, that a millionth part of a grain of arsenic or opium, will act with better effect upon certain diseases, than much larger quantities. This doctrine of the homœopathist, applies with perfect truth to the application of certain salts to the soil. It is often surprising to notice the effect of a single grain of lime or potash in a hundred of the soil, doubling, tripling, and often quadrupling the quantity of the productions in a single year. This result must be due, in part, to the electrical effect which this small addition produces; hence we may learn both the importance of ascertaining the composition of soils by accurate analysis, and of improving them by adding those substances which they require.

In conclusion, it may be remarked, that the agents, considered in this and the preceding chapter, are not only the great causes of change and reproduction in the vegetable, but also in the animal and mineral kingdoms. Most of them are the natural powers ordained of God for the government of the natural world. A correct knowledge of them will help us to explain the almost infinitely varied and mysterious phenomena which are every day presented to our minds; and when we have begun to understand their agency, when we can trace the chain of effects to the ultimate cause we shall find, that they will present subjects of deep and delightful reflection.

They will enable us to gain a deeper and more profitable insight into the mysteries of nature, and to be better fitted to discharge our duties as citizens and as men; our toils will become lighter, because we shall find in our employment an interest and a soul.

CHAPTER III.

PRODUCTIONS OF THE VITAL PRINCIPLE—THEIR CHARACTER, COMPOSITION, SOURCES AND ASSIMILATION.

Having in the preceding chapters given a general account of the *vital principle*, and the agents which act upon it, including the general processes of vegetation, we come now to describe the *productions* of this power; for, in opposition to the views of many chemists and vegetable physiologists, we still insist, that this power *actually exists* in vegetables, and that we have good reasons for ascribing to it, as a principal agent, the various compounds which are found in vegetable bodies. The character of these compounds is wholly different from that produced by a chemical or a mechanical agent. Their composition cannot be accounted for by ordinary chemical changes; and the source and assimilation of their simple constituents, teach the same doctrine. This chapter, therefore, will be devoted to the discussion of these topics.

SECT. 1. *Character and Composition of the Vegetable Productions.*

The productions of the vital power are very numerous. They are called *vegetable* or *proximate principles*, such as sugar, gum, and starch; and differ, materially, in their character and composition, from *inorganic* bodies. The vegetable principles exist in plants, already formed; and the processes by which they are separated, are called *proximate analysis*.

These processes are various, and are described in works on elementary chemistry. Many of them, however, are well known to farmers, such as the obtaining of starch from potatoes or wheat, of sugar from the juice of the maple, beet-root, etc. The vegetable *proximate principles* are all decomposed by a red-heat, and are converted chiefly into carbonic acid and water. When subjected to *ultimate analysis*, they are found to be composed of carbon, oxygen, hydrogen and nitrogen. Small quantities of phosphates, sulphates, metallic oxides and earths are found in vegetable bodies; which, though essential to them, constitute but a small portion of their substance, and are called the *inorganic* constituents of plants. The vegetable, as it is formed in nature, contains alkalies and metallic oxides, in combination with the *proximate principles*, although the latter, as such, contain no metallic bases.

The simple bodies O. C. H. N. are found combined in various proportions. Generally a larger number of equivalents are united to form the *organic* than the *inorganic* body. Some organic bodies are composed of two, some of three, and others of four simple bodies; and the proportions vary from one to seventy equivalents or more, but in inorganic bodies, rarely more than seven equivalents of the same elements are found.

I. *Organic principles*, composed of two ingredients, are of four kinds.

1. Compounds of carbon and hydrogen, as in oil of turpentine, which is composed of $C^{10}H^{8}$,* and in the volatile and fixed oils.

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* It will be recollected that the four bodies, carbon, oxygen, hydrogen and nitrogen, are represented by their initial letters, C. O. H. N. and the number of equivalents are represented by figures placed as indices; thus C^{2}, O^{3}, signifies a compound formed of 2 equivalents, or 12 parts by weight of carbon, and 3 equivalents, or 24 parts by weight of oxygen. The equivalent of hydrogen is 1, oxygen 8, carbon 6.12, and nitrogen 14. We have only to look at the indices, to ascertain the number of equivalents in any compound, and by multiplying that

2. Of hydrogen and oxygen, as water, which is formed of OH.

3. Of carbon and oxygen, as oxalic acid, composed of C^2O^3.

4. Of carbon and nitrogen, as cyanogen, composed of C^2N.

II. *Organic principles, composed of three constituents*, are much more numerous than the preceding.

1. The most common combinations are carbon, hydrogen and oxygen. Sugar, gum, etc. and the greatest number of acids, are thus constituted.

2. Compounds of carbon, hydrogen and nitrogen, as azulmic acid which is thus constituted, C^5HN^2.

3. Compounds of carbon, oxygen and nitrogen, as carbazotic acid, $C^{15}N^3O^{15}$.

III. *Organic principles of four constituents*, as *aspartic acid*, $C^8H^7NO^8$. Almost all the alkalies contain these four substances.

Of the simple substances, carbon is most abundant, and next are oxygen and hydrogen; while nitrogen, although not absent from any part of a plant, exists in very small quantities in all.

But the substances which constitute the principal mass of every vegetable, are compounds of oxygen and hydrogen (in the proportions to form water) and of carbon. In a second class, oxygen is in excess, as in the numerous organic acids. In a third class, as the volatile and fixed oils, carbon and hydrogen exist, but no oxygen, and in a fourth class nitrogen is added, as in vegetable albumen, in indifferent substances, and in some acids.

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by the number representing the equivalent for that substance, the exact amount by weight may be obtained. The whole added together gives the equivalent of the compound, which is also represented by numbers. This mode of represention is now adopted by all chemical writers, and seems useful to present the compounds to the eye in a condensed form.

The vegetable principles are divided by Thompson into the four following classes.

I. Acids. II. Alkalies. III. Intermediate bodies. IV. Neutral bodies.

The substances, classed under these heads, are not all the products of the *vital principle.* Some of them result from decompositions, and hence are the products of death rather than of life.* A large number of the products of vitality are inserted in this section as a convenient reference for those who have not better sources of information. The agricultural reader can omit them, if he chooses, altogether.

I. *Acids.* The number of acids, *derived* from the vegetable kingdom, amount to 116, but a few of this number are of any particular importance to agriculture. The following are the principal vegetable acids. Oxalic, citric, tartaric, benzoic, meconic, acetic, malic and prussic acids. All, save the last three which have been obtained only in a liquid state, are white crystaline solids. All are more or less soluble in water. All are *sour to the taste*, with the exception of gallic and Prussic acids, the first of which being astringent, and the latter having the taste of bitter almonds.

1. *Oxalic acid* (C^2O^3=36.24)† is found in *wood sorrel*, (*Oxalis acetosella*,) and is the cause of its sour taste. It also exudes from the chic pea (*cicer arietinum*). Many vegetable principles, such as gum, starch, etc. are converted into this acid by nitric acid. It exists in small, slender crystals, resembling *epsom salts*, for which it is sometimes mistaken with fatal consequences. It is a powerful poison with a strong acid taste. It is distinguished by its power of decomposing all salts of lime, and forming with the base an insoluble salt. This acid is found in combination with lime (*Oxalate of lime*) in several species of lichens. When

* For a complete description of all the vegetable principles, the reader is referred to Thompson's Chemistry of Organic Vegetable Bodies.

† The expression, C^2O^3=36, when translated, would read thus: Oxalic acid is composed of 2 equivalents of carbon, or 12.24 parts by weight, and 3 equivalents of oxygen, or 24 parts by weight, which makes an equivalent of oxalic acid equal to 36.24; that is, when oxalic acid combines with any other body, it always unites 36 parts by weight.

first precipitated, the *oxalate of lime* ($C^2O^3CaO^2HO=82.74$) is a snow-white, floculent powder.

*Oxalate of potassa** is commonly called the *essential salt of lemons*, and is used to remove spots and iron rust from linens.

2. *Citric acid* ($C^4H^2O^4=60$) is found in many acidulous fruits, such as limes, lemons and oranges. It is distinguished by forming an insoluble salt with lime, and is used in preparing lemon syrup.

3. *Tartaric acid* ($C^4H^2O^5=66.24$) exists in acidulous fruits, especially in the juices of the mulberry and grape, usually in combination with lime or potassa. It is the substance used with soda for an effervescing drink. *Bitartrate of potassa* is found in old wine casks, and when purified, is called *cream of tartar*, and is used in medicine. *Tartar emetic* is a compound of tartaric acid with potassa and antimony, and is neutralized by astringents, such as tea or Peruvian bark, in case too large a dose is taken.

White Rochelle salt is formed of potassa and soda, combined with tartaric acid.

3. *Benzoic acid* ($C^{14}H^5O^3=123$) exists in gum benzoin, in the balsams of Peru, and some other vegetable substances. It is distinguished by its volatility and aromatic odor; although, when perfectly pure, it has no smell. When sublimed, it forms long, flat, prismatic nodules, having a beautiful satin lustre.

4. *Meconic acid* ($C^7H^2O^7=100,84$) is found in the poppy, in combination with morphia, and crystalizes in white, transparent scales.

5. *Gallic acid* ($C^7H^3O^5=85$) is found in *gall-nuts* and in the bark of trees. It forms ink by combining with the *proto-sulphuret of iron.*

6. *Tannic acid* ($C^{18}H^8O^{12}=212$) exists also in gall-nuts, in tea and vegetable astringents, and is the cause of their astringency. With *gelatine* or *glue* it forms an insoluble compound, which is the basis of *leather;* hence its use in tanning hides. Tannic and gallic acids possess the property of preserving bodies from decay.

7. *Acetic acid* ($C^4H^3O^3=51,48$) exists in the sap of many plants. It is well known under the name of *vinegar.* It forms numerous salts with inorganic bases, such as *acetates of lead* (su-

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* When an acid combines with an alkali or metallic oxide, the substance formed is called a *salt*, and the name of the acid changes its termination into *ate*, or if the acid terminate in *ous*, into *ite*.

gar of lead); of copper (verdigris); and many others, which are useful in the arts.

8. *Malic acid* ($C^4H^2O^4=60$) is obtained from the juice of apples, barberries, plums, elder-berries, currants, strawberries, raspberries, etc. It is distinguished from the preceding acids, by forming soluble salts with lime.

9. *Prussic acid* ($C^2NH=27$) is obtained by the distillation of laurel leaves, from the stones of the peach, cherry, and bitter almonds. This is the most violent poison with which we are acquainted.

The above are only a few of the vegetable acids. They impart to fruit that tart, pleasant taste which forms their distinguishing characteristic.

II. *Alkalies.* This class includes about thirty-seven substances, all discovered since 1817. Those plants which are remarkable for their poisonous or medicinal properties, contain an alkaline principle. Those most important in this connection are Morphina, Narcotina, Cinchonina, Quinina, Strychnina, Emetina, Nicotina, Conicina, Solanina, Parillina. They are compounds of hydrogen, oxygen, carbon and nitrogen; and their composition will be indicated by symbols, as in other cases.

1. *Morphina* ($C^{34}H^{18}NO^6=284$) is the narcotic principle of opium, and constitutes about $\frac{1}{16}$ of its weight. It is a well-known poison, of an astringent bitter taste. It is used in medicine to allay pain. When opium has been administered as a poison, a skilful chemist will detect a single grain of the morphina in 700 grains of water. It is contained in the capsule of the poppy, from which it is generally obtained. It combines with a great many organic and inorganic acids; and the salts, thus formed, are used extensively in medicine.

2. *Narcotina* ($C^{40}H^{20}NO^{12}$) is found in opium. It is not injurious to man, but fatal to dogs!

3. *Cinchonina* ($C^{20}H^{12}NO1\frac{1}{2}=158$) is found in Peruvian bark (*cinchona nitida* or *condaminea*), and imparts to it its value as a medicine. It has a peculiar bitter taste, which is not perceived at first, in consequence of its insolubility. It crystallizes in delicate prismatic needles, or in white translucent tufts; and, by uniting with acids, forms a great number of organic salts.

4. *Quinina* ($C^{20}H^{12}NO^2=162$) is also found in connection with Cinchonina and is used for a similar purpose. The *sulphate* of quinina is manufactured on a large scale, and sold as *Quinine.* It is intensely bitter, and is of great value in certain diseases.

5. *Strychnina* ($C^{30}H^{16}NO^{3}=237.75$) is found in the nux vomica (*strychnos nux vomica*), the St. Ignatius bean (*strychnos ignatia*), and the upas. It is an intensely bitter substance, and one of the most *violent poisons* yet discovered. Its action is accompanied with symptoms of locked-jaw.

6. *Emetia* or *Emetina* ($C^{35}H^{25}NO^{9}=308$) is found in several plants, especially in the roots of the *cephælis emetica, ipecacuanha*, and possesses most powerful emetic properties. It generally exists in the form of a yellowish powder. Six, or at most twelve grains, occasion violent vomiting, followed by death.

7. *Nicotina* is the peculiar principle of tobacco, a most virulent poison. It has not been fully analyzed, but is supposed to contain more nitrogen than any of the other alkaloids.

8. *Conia* or *Conicina* ($C^{12}H^{14}NO=108$) is the active principle of *conium maculatum* or hemlock, and is the most violent poison known, with the exception of hydrocyanic or prussic acid. It has the appearance of a yellowish liquid oil, with a strong, penetrating smell, and acrid and corrosive taste. A single drop, put into the eye of a rabbit, killed it in nine minutes. Three drops, used in the same way, killed a strong cat in a minute and a half. It is a common opinion, that mineral bodies are the most poisonous, but it is not the case, as the two most violent poisons known, are derived from vegetables.

9. *Solanina*, ($C^{28}H^{21}N\frac{1}{2}O3\frac{1}{2}$ M. Henry,) is found in the berries of the *solanum nigrum*, the *solanum dulcamara*, or common Nightshade, and in potato-balls. It is found also in the potato-root, after germination commences, and in the epidermis. It is *an acrid, narcotic poison*, and care should be taken not to use this root, after germination has commenced.

Parillina, ($C^{9}H^{8}O^{3}$) is found in the *smilax sarsaparilla*, or the common sarsaparilla of the shops, a substance used in the preparation of mead, beers, etc. It diminishes the rapidity of the circulation, and acts as a sudorific, producing perspiration, and of course debilitates the system. In a pure state, it is a white powder, with a sharp and bitter taste, slightly astringent and nauseous.

Class III. Intermediate Bodies. In this class are included several vegetable principles, which have not yet been shown to possess, either alkaline or acid properties. The principal of which, are coloring-matters, fixed and volatile oils, resins and gum-resins.

1. *The coloring-matters* of vegetables, are usually diffused through other proximate principles. The most common veg-

etable colors, are *green*, *yellow*, *blue* and *red*. But all the colors of dyed-stuffs, are produced from blue, red, yellow and black, though the latter does not exist in the vegetable kingdom, but is formed by adding mineral bodies to the acid of gall-nuts or logwood.

Blue dyes are derived from the indigo plant (*indigofera*), a genus of plants of which there are sixty species. They are found in India, Africa and America. *Litmus* has a blue color, and is used as a chemical re-agent.

Red dyes are derived from the *cochineal*, an insect which feeds on one species of the cactus; from lac, archil, madder, Brazil-wood and logwood.

Lac is a resinous substance, derived from the *ficus Indica* and *religiosa*, and is commonly known as shell-lac. *Archil*, is obtained from a species of lichen (*parmelia roccella*), the best quality of which is found in the Canary Islands.

Madder is the root of the *rubia tinctorum*, a plant cultivated in countries bordering on the Mediterranean Sea. This plant is also used for a great variety of colors, forming by the addition of mineral substances, madder-yellow, madder-orange and madder-brown.

Brazil-wood is found in Brazil, and is obtained from several species of the *cæsalpina* (sapan, crista, etc.). The red coloring matter of this wood, is rendered *yellow* by acids, and *violet* by alkalies.

Logwood is the wood of the *Haematoxylon Campeachianum* found in Jamaica, and the eastern shores of Campeachy. This wood is chiefly employed by the calico printer, to give cotton a brown or black color.

Yellow dyes are obtained from the quercitron bark, which is taken from (*quercus nigra*), a large tree growing in this country; from tumeric (*curcuma longa*), saffron (*crocus sativus*), and from fustic (*morus tinctoria*), a large tree which grows in Brazil; from *weld*, which is the dried leaves of *reseda luteola*, a European plant; from Persian berries (*rhamnus infectorius*); from sumac (*rhus coriaria*), which grows spontaneously in Italy and the south of France.

2. *Fixed oils* are usually obtained from seeds, as the almond, linseed and poppy-seed. Olive-oil is extracted from the pulp around the stone. After being boiled, these oils dry more rapidly, and are then used in forming paints; when mixed with lampblack, they constitute *Printer's Ink*. In drying rapidly, these oils absorb so much oxygen, as to take fire spon-

taneously, an accident which frequently occurs when cotton or wool in large quantities is moistened with them. The principal fixed oils, are olive, croton, palm, cocoanut and linseed oils.

3. *Volatile oils* give a peculiar flavor to plants, called *aromatic.* They are obtained by distillation of leaves, or by expressing them from the rinds of certain fruits, such as *orange*, *lemon*, *burgamot*, etc. Like the fixed oils, they burn with a clear, white flame. The principal volatile oils, are oil of turpentine, lemon, anise, juniper, camomile, caraway, lavender, peppermint, rosemary, camphor, cinnamon, cloves, sassafras, mustard and bitter almonds.

4. *Resins* are the *juices* of plants, such as exude from pines and balsams; they are generally solid, brittle, and without taste. The resins are well known, under the names of *rosin*, copal, shell-lac, mastic, dragon's blood, guaiacum, etc. The uses of these are well known. Copal is the basis of all varnishes.

5. *Gum-resins* are the hardened juices of several species of plants, which, when cut, give out a milky juice, more or less thick; these are numerous, and many of them are valuable medicines. Among them are aloes, asafœtida, ammoniac, galbanum, gamboge, myrrh, olibanum, opium, etc.

Aloes are obtained from several species of trees, especially the *aloe vulgaris*, from the leaves of which it exudes when cut. It is of a reddish-brown color, and of an intensely bitter taste.

Ammoniac is obtained from the *dorema ammoniacum*, and is used in medicine, but is the least powerful of all the fœtid gums.

Asafœtida is obtained from *ferula asafœtida*, a native of Persia; it exudes from the roots when cut, in the form of a milky juice. Its taste is acrid and bitter; its smell strongly alliaceous and fœtid. It is employed in medicine, especially in cases of hysteria, asthma and hooping-cough.

Galbanum is obtained from the plant *Galbanum officinale*, a native of Persia; its taste is acrid and bitter, and its smell peculiar. It is used in medicine for similar purposes with ammoniac, but acts with less energy than asafœtida.

Gamboge is obtained from a tree of Siam, and also of Ceylon; but the species is doubtful. It is sold in commerce, under three forms, *pipe*, *cake* and *lump gamboge.* It is employed in water-colored painting, forming a pure and fine yellow. It is also used in medicine as a cathartic.

Myrrh is obtained from the *balsamadendron myrrha;* a tree which grows in Arabia and Abyssinia. It exudes from the tree in the state of a yellowish-white liquid, which soon hardens into a brittle solid, of a transparent, reddish-brown color, and of a bitter and aromatic taste. It was known and used by the ancients. In medicine, it is considered as a tonic. The alcoholic tincture is used as a wash for the teeth.

Olibanum is the frankincense of the ancients. According to Lamark, the Arabian variety is obtained from the *amysis gileadensis*, while Mr. Colebrook derives the Indian olibanum from a large tree growing on the mountains of India, *boswella serrata.* It is a brittle, white-yellow substance, of an acrid and aromatic taste, and, when burnt, diffuses an agreeable odor, on which account it is much used as a perfume.

Opium is a sedative gum-resin, which exudes from the heads of the *papaver somniferum*, or poppy, great quantities of which are used in medicine. It is also taken in large quantities as a stimulant, in which case it is highly poisonous.

Class IV. Neutral Substances are those vegetable principles which possess, neither the properties of acids nor bases, and which, so far as is known, do not combine in *definite proportions** with other substances. Under this class are arranged a very great number of useful substances. Those that are of particular interest to the agriculturist, may be included under the following heads: *sugars*, *amylaceous substances*, *gums*, *glutenous substances*, *caoutchouc*, *extractive*, *and bitter principles.*

1. *Sugar* ($C^{12}H^{10}O^{10}=162$) is a term applied to substances characterized by their sweet taste. It is found generally in the juices of plants, from which it is extracted by boiling or evaporation. The sap of *common sugar* is obtained from the sugar-cane (*arundo saccharifera*), the sugar-maple (*acer saccharinum*), and from the beet-root. This latter source of sugar, was introduced into France by Bonaparte, during the war between France and England, and in the year 1827, the quantity manufactured was 2,650,000 lbs. The modes of making sugar, derived from these sources, are various, and can only be alluded

* Most bodies, as the acids and alkalies, combine with other bodies in *definite proportions ;* that is, definite quantities of one body combine with definite quantities of another body, to form a third body. See *Introduction.* But there are also a large class of bodies, both organic and inorganic, which do not observe this law, and are said to unite in *indefinite proportions.* Water and sulphuric acid, for example, will unite in all proportions. Most substances which are held in solution in water, unite with it in indefinite proportions, up to the point of *saturation ;* such as salts, sugars, gums, etc.

to in this place. When the sugar-cane is used, the green canes are ground in a mill, and the juice evaporated or boiled.

The sugar-maple is tapped, and the juice received in buckets or troughs, and then boiled until the water is all evaporated. The beet* is sliced and pressed to obtain the juice. Many other vegetables contain sugar, as the sap of the birch, butternut, elm, and a great variety of trees; but only those which have been mentioned are employed for this purpose to any considerable extent. It is a substance of universal consumption.

Liquid sugar is distinguished from common sugar, by the fact, that it is incapable of *crystallization.* It exists in various fruits and vegetable juices. It constitutes a considerable portion of the molasses in the sugar of the cane. It exists also in the grape, peach, apple, and other fruits.†

Zea Maiz, or Indian corn, also contains liquid sugar. *Sugar of grapes* is not so white as common sugar, but it crystallizes much more readily.

Manna was long regarded as a substance which fell from the heavens, until it was found to exude from several trees, of which a species of ash (*fraxinus ornus*), found in Sicily, is the most productive. Manna has the form of oblong globules, of a yellowish-white color, and is used in medicine. A substance called *mannite*, or mushroom sugar, is similar to manna.

Sugar of liquorice is obtained from a plant growing in Spain. The root is the common liquorice-root, and the black balls, sold under the name of liquorice-balls, is the sugar.

2. *Amylaceous substances* include common starch, hordein, lichnin, inulin, lignin, diastase, etc.

Common starch is secreted in most of the grains, the potato, arrow-root, tapioca, sago, and, in small quantities, in nearly all trees, seeds and fruits. When wheat-flour is formed into paste, held under a stream of water, and kneaded until the water runs off clear, a tough substance remains called *gluten*, while there is deposited in the water a white sediment, which is known as *common starch.*

Arrow-root is a very pure starch, extracted from the root of the *maranta arundinacea*, a plant which is native in South America.

Tapioca is also a very pure starch, obtained from the root of a South American plant, *iatropha marihot.* The roots are sub-

* Thompson's Organic Bodies, p. 629. Chaptal's Ag. Chemistry. Child's Beet Sugar.

† Prout.

jected to pressure, and a juice extracted, which yields it in the greatest abundance. It is a fine white powder, destitute of taste and smell, and very much resembles starch.

Lignin ($C^{15}H^{10}O^{10}=180$.) This name is given to the fibrous portions of wood, which remain after digesting common wood in water, muriatic acid and alkalies. It constitutes the skeleton of the trunk and branches of trees. The quantity of lignin varies in different kinds of wood, but generally there are 96 parts in 100. Sulphuric acid converts it into *sugar*, and potash into *ulmin*. It is the substance which remains, when wood is converted into charcoal, or rather it is the lignin which is converted into charcoal by heat. It may be made into excellent bread. The inner bark of flax and hemp, and the fibres of cotton, are probably the same substance. It is by far the most abundant substance in vegetables.

Fungin is a peculiar vegetable principle derived from mushrooms, and approaches in its chemical character closely to woody fibre.

Diastase is a substance obtained from *malted barley*, and exists in the seeds, and also in oats and wheat. It has the property of converting starch into sugar, and is used in the preparation of *dextrine*, a substance employed for raising bread. It is supposed to be the peculiar principle of ferments, and hence its great use in culinary operations.

3. *Gums* are the exudations of several trees, such as the plum, peach, apple, cherry, etc. but the principal *gums* are *gum arabic*, from the *acacia, vera and arabica*, and *gum senegal*, from *acacia senegal.*

Lintseed, when macerated in water, is converted into *mucilage*, and when this is evaporated to dryness, it leaves a translucent matter behind, similar to gum. The different kinds of gum are classed by Thompson under three vegetable principles, *arabin*, *bassorin* and *cerassin*. *Gum arabic* is principally composed of arabin, and is well known in the shops. *Gum senegal* is of similar composition. *Mucilage of lintseed* is different from the preceding, but one part of it contains *arabin*.

Gum Bassora, *gum tragacanth* and *gum kuteera*, contain *bassorin*, and are articles of commerce. These gums are used by calico printers. The gum from the cherry, apricot, plum, peach and almond tree, contain *cerasin*, which is the cause of their insolubility. Many of the gums are easily soluble, and are used for varnishes. They are also used in medicine to a considerable extent.

Calendulin is a peculiar principle found in the marigold; it is a yellowish, translucent, brittle substance.

Saponin is another peculiar principle, found in a root which grows in Greece and eastern countries; it may be used for *soap.*

4. *Glutinous substances.* When wheat-flour is kneaded into paste with a little water, it forms an elastic, soft and ductile mass. When this is washed under a stream of water until it runs off colorless, there remains a tough, elastic substance, of a gray color, called *gluten.* It was discovered in 1742, by Beccaria, an Italian philosopher. It has scarcely any taste, and adheres tenaciously to most bodies with which it is brought in contact. It is the substance which renders bread tough, and enables the dough to rise by ferments. It exists in all kinds of grain, and their value depends upon its quantity. Modern chemists have resolved it into four distinct principles, *albumen, emulsin, mucin* and *glutin.*

Vegetable albumen is obtained by digesting the gluten of wheat in alcohol, until everything soluble is taken up. It is a bulky substance of a greyish color, soluble in water, and is the substance in the seed, which takes an important part in germination.

Emulsin ($C^{24}H^{23}N^{4}O^{9}$) is found principally in almonds, and resembles starch, when dissolved in water. It has the peculiar property of decomposing *amygdalin*, and of forming hydrocyanic acid, and the volatile oil of bitter almonds.

Mucin is taken up by hot alcohol, when the gluten of wheat is put into it. It burns like animal matter, and is more soluble than gluten.

Glutin ($C^{8\frac{1}{2}}H^{7}N^{1}O^{3}$) is also taken up by boiling alcohol with the gluten of wheat, and is obtained after precipitating all the mucin. It is a yellow, translucent substance, almost insoluble in water, and generally exists in wheat in connection with starch.

Zein is a name given to the gluten of *zea mais*, or Indian corn. It differs from the gluten of wheat by containing less nitrogen.

Viscin ($C^{13}H^{10}O^{2}$) is a soft elastic substance, of a brown color, identical with bird-lime. It adheres firmly to the fingers like glue, and exists in several species of *acacia.*

Pollenin ($C^{11}H^{20}O^{10}$) is derived from the pollen of the *pinus, abies* and *sylvestris*, and is supposed to characterize every species of pollen.

Legumin is a vegetable principle, found in the fleshy cotyledons of all papilionaceous plants, such as peas, beans, etc. and seems to be intermediate between gluten and vegetable albumen.*

Amygdalin ($C^{40}H^{26}N^{1}O^{22}$) is found in bitter almonds.

5. *Caoutchouc* is obtained from the milky juice of several species of trees in South America, and in the East Indies. It is is well known as *India-rubber.*

6. *Extractive.* The term extractive is now restricted to what is obtained by macerating vegetables in water, and evaporating the infusion to dryness. There is a great variety of these extracts, and they are used extensively in medicine, in which case they are generally preserved in alcohol.

7. *Bitter Principle.* Many vegetable substances have an extremely bitter taste, and, on that account, are employed in medicine. This is the case with the roots of the *quassia gentian*, hop, camomile, worm-wood, etc.

The following are some of the most remarkable bitter substances which have been examined.

Quassite, obtained from the *quassia amara* and *excelsa. Gentianite*, from the seeds of the *gentiana lutea. Cytisite*, from the seeds of the *cytisus laburnum. Bryonite*, from the root of the *bryonia alba*, or *white bryony. Centaurite*, from the leaves of the *centaurea benedicta*, or *blessed thistle. Arthanitite*, from the *cyclamen Europeum*, or *sow-wort. Bitter principle of wormwood*, from the *artemisia absynthium*, or *worm-wood. Colocynthite*, from the *cucumii colocynthii*, or *colocynth* of pothecaries. *Bitter principle of aloes. Xanthropicrite. Berberite*, from the bark of the common barberry, *berberis vulgaris. Lupinite*, from the seeds of the *lupinus albus. Phloridzite*, from the bark of the apple, pear, cherry and plum tree.

It would be nearly useless to enumerate any more substances, as the peculiar products of vitality, for but little more can be done in this work, than to mention their names. These are mostly technical and unintelligible to the farmer. Perhaps too many have already been inserted. The object is simply to give the reader, some idea of the great number of compounds, which

* There are found in animal bodies three substances, which appear to be identical with gluten, vegetable albumen and legumin; they are *casien*, the curd of cheese; *albumen*, or the white of eggs; and *fibrin*, the substance which constitutes the muscular fibre of animals It is probable, that these substances are derived by animals from vegetables. They contain large quantities of nitrogen, and hence their use for manure.

have been found in the vegetable kingdom, and which cannot, with but few exceptions, be formed by any known chemical agents. This enumeration will perhaps lead some scientific farmers to examine more fully the vegetable principles, and to study in works where they are found fully described, their characters and uses.

It may, however, be useful, and much more intelligible to the common reader, to describe the sources of several articles of food and of medicine, as they exist in the roots, wood, bulbs, leaves, fruit, or seeds of plants.

I. *Roots.* The principal roots, employed in medicine and the arts, are the following.

1. *Beet-root* (*beta vulgaris*). There are two varieties, the red and the white beet. This is a well known vegetable. It contains from 5 to 10 per cent. of sugar, generally from 8 to 9 per cent.; hence its use for this purpose.

2. *Carrot* (*daucus carota*). This is also a well known root. It is used for fattening cattle, and is preferable to the beet for that purpose. It contains sugar, and a peculiar principle, called *caratin.*

3. *Rhubarb* (*rheum plamatum, australe, undulatum,* etc.) Three varieties of rhubarb are known in commerce, Russian, Turkey, East India or Chinese rhubarb. It is a yellow root possessing powerful purgative properties, for which it is used in medicine.

4. *Rattle-snake root* (*polygala senega*), is a native of Virginia, and is employed by the Indians as a cure for the bite of the rattle-snake. The peculiar vegetable principle upon which this effect depends, is called *senegin.*

5. *Jalap* (*Ipomea jalappa*), is a well known active cathartic. It is a native of Mexico, but the best jalap comes from Vera Cruz and South America. The active properties are supposed to be due to the resin which it contains.

6. *Gentian* (*gentiana lutea*), grows in the mountains of Switzerland and America, and is a bitter root, yielding to water an extract, which produces intoxicating effects.

7. *Valerian* (*valeriana officinalis*), is a root much used as an anti-spasmodic in epilepsy, etc.

8. *Horse-radish* (*cochlearea armorica*), is a root of an acrid taste, which is due to a small quantity of volatile oil.

9. *Sweet-flag* (*acorus calamus*), contains a volatile oil, inuline, gum-extractive, resin, with phosphate and muriate of potash.

10. *Ipecacuana* (*callicocca ipecacuana*), common ipecac, is the root of a plant which grows in Brazil. The root is about the thickness of a quill, and varies considerably in color. When pounded, it forms the mildest and safest emetic.

11. *Sarsaparilla* (*smilax sarsaparilla*), is a native of South America, and is used in medicine in certain chronic diseases, and in *syphilis*.

12. *Ginger* (*amomum zingiber*), is a plant found in India, and well known to the ancients. It is a whitish root, but when powdered as in common ginger, it is yellowish. This root makes a very delicate preserve.

13. *Pomegranate tree* (*punica granatum*), has been employed in medicine. It contains a substance similar to mannite, which has been called *grenadia*.

14. *Crameria ratanhia* is a root found in South America, and yields a powerful and safe astringent matter, used in medicine. The active principle exists in the bark of the root.

II. *Bulbs* are the tubercles connected with the roots of vegetables, analogous to buds. The following are the principal bulbs or tubers, which are used for food, in medicine, and the arts.

1. *Potato.* This is the bulb of the *solanum tuberosum*, which is found wild in the mountains of Chili. They contain but little nitrogen. They also contain the poisonous alkali, solenin, which exists in the epidermis when they begin to germinate. They are generally composed in one hundred parts, of eight parts of fibrin, ten of starch, one of gum, acids and salts, and eighty-one of water. Their uses as food are well known.

2. *Jerusalem artichoke* is a bulbous root of the *helianthus tuberosus*, a South American plant. It is very productive, of a sweetish taste, very watery, and very valuable, as they will grow on a light soil, and yield abundantly without much cultivation. One acre sometimes yields sixty or seventy tons. It is singular, that this valuable root is not more cultivated.

3. *Garlic* is the bulbous part of the root of the *allium sativum*. It is found in Sicily, is remarkable for its strong smell and taste, and was celebrated by the ancients, both as an article of food, and as a medicine.

4. *Onion* is the root of the *allium cepa*, a well known vegetable, used as food.

5. *Squill* is the bulb of the *scilla maritima* a native of Spain,

Sicily and Syria. Its bulb is nearly the size of a human head, is shaped like a pear, and formed of fleshy scales. It has no smell, but its taste is bitter, nauseous and acrid. It is used in medicine to excite nausea and vomiting.

6. *Saffron* (*colchicum autumnale*) is used in medicine for the *gout.* The tube is egg-shaped, and covered with a brown membranous coat. The recent bulbs have no smell, but are bitter, hot and acrid to the taste. It is poisonous.

III. *Woods.* The wood of different trees differs but little in composition; generally about forty-eight or forty-nine parts of carbon, six of hydrogen, and forty-four or forty-five of oxygen, are found in one hundred.

The vegetable fibres in herbaceous plants are similar to the wood of trees. Of these, hemp, flax and cotton are the most important, because of their use in the arts. These substances, however, might, with equal propriety, be regarded as the inner bark.

Flax. The fibres of flax are "transparent, cylindrical tubes, articulated and pointed like a cane." It was known to the ancients, and has been an article of universal consumption.

Hemp is precisely similar in composition with flax, but has a coarser fibre.

Cotton is the soft down which envelopes the seeds of different species of *gossypium*, from which plant the cotton of commerce is procured. "The fibres of cotton are transparent, glassy tubes, flattened and twisted around their own axis." By this test the *fine linen* of Egypt is found to be linen, and not cotton, as some interpreters of the Bible have supposed.

"Paper is prepared from hemp, cotton and linen rags. These rags are bleached and reduced to an impalpable pulp." This pulp is spread equally on a wire sieve, and the paper placed upon cloths to dry; after which it is sized and pressed.

IV. *Leaves.* The leaves of plants much resemble each other in appearance, but contain various vegetable principles.

1. *Senna* is the leaf of the *cassia acutifolia* and *obovata*, natives of upper Egypt and Nubia. It is a valuable cathartic.

2. *Belladonna* is the dried leaves of the *atropa belladonna*, or *deadly night shade.* It is poisonous, but used in medicine.

3. *Tobacco* is formed from the leaf of the *nicotiana tabacum*, a native of Tabaco in Mexico, from which it receives its name. It is a well known, and much used narcotic poison. It contains at least eighteen different substances. *Nicotina* is the cause of its poisonous effects.

4. *Fox-glove*, the *digitalis purpurea*, is a well known vegetable, the leaves of which were introduced into medicine by Dr. Withering.

5. *Tea* is composed of the dried leaves of the *thea bohea*, and *thea viridis*, natives of China and Japan. The different varieties of tea, are all derived from these two species. The leaves of this plant are not fit for use, until the shrub has vegetated three years. The leaves are collected and exposed to the steam of boiling water, and *every leaf* is then rolled up with the hand, put upon plates of copper, and held over the fire, until they are shrivelled. To this heating process tea owes its peculiar flavor. Its uses are well known. It is a powerful stimulant, acting upon the nervous system, and producing an exhilarating effect.

6. *James' tea* is the leaf of the *ledum latifolium*, a native of this country.

7. *Paraguay tea* is the leaf of a native plant of South America, of the *holly* genera, and is used as a tea. It is a stimulant, and, if used in excess, occasions intoxication and *delirium tremens*.

8. *Isatis tinctoria*, or *woad*, is the plant from which indigo is obtained.

9. *Asparagus officinalis* is a valuable vegetable, the young shoots of which are used for food.

V. *Seeds and fruits* constitute the most important articles of food. They contain all the elements necessary for the support of animals.

1. *Wheat* is the seed of the *triticum hybernum*, winter wheat, and *T. aestivum*, or summer wheat, the most important of all the smaller grains. Two or three other species have been cultivated. Its properties and uses are well known. A sample of French wheat, analyzed by Vauquelin, yielded seventy-one parts of starch, ten of gluten, five of sugar, three of gum, and ten of water in one hundred.

2. *Rye* is the grain of the *secale cereale*. It is subject to the disease called ergot, which is a species of fungus plants, of a long, black appearance, blunt angles, and about one inch in

length. By some the ergot is regarded as the effect of an insect. This substance is a violent poison. Rye is similar to wheat in composition, but contains less starch and gluten.

3. *Oats* are the seeds of the *avena sativa*, and are a valuable fodder for horses. In some countries, as Ireland, the oat is employed for bread.

4. *Barley* is the seed of the *hordeum vulgare*, and is used for bread, malt liquors, and for obtaining ardent spirits.

5. *Rice* is the seed of the *orysa sativa*, a well known article of food, especially in warm countries.

6. *Maize* or *Indian corn.* The *zea* maize is a native of this country, but is now cultivated in Europe, and is one of the most valued of our grains. It is composed of starch eighty-four, zein three, albumen three, gum two, sugar two, water six, in one hundred.

7. *Peas* are the seeds of the *pisum sativum*, and constitute a very nutricious article of food.

8. *The small bean* (*vicia faba*), is used as an article of food, and also,

9. *The kidney bean*, (*phaseolus vulgaris*). They contain a large quantity of animo-vegetable matter.

10. *Lentiles* (*ervum lens*), contain a larger quantity of animo-vegetable matter than the kidney bean.

11. *Orange* (*citrus aurantium*), and (*citrus medica*), are well known fruits which are employed both in medicine and for food.

12. *Cherry* (*prunus cerassus*), are a cultivated fruit, of which there are several varieties.

13. *Almond, Peach and Apricot* are quite different fruits, but the trees are botanically identical (*amygdalus communis*).

14. *Pear* (*pyrus communis*), *apple* (*pyrus malus*), are too well known to need description.

15. *Gooseberry* (*ribes grossularia*), Black currant (*R. nigrum*), Red currant (*R. rubrum*), are valuable acid berries.

16. *Grapes* are the fruit of the *vitis vinifera*, and are extensively cultivated in France and the south of Europe, both for the wine which their juice yields, and for raisins.

17. *Mango* is the fruit of the *mangifera indica* or *domestica*, a native of India. The fruit varies from the size of an apricot, to that of a pear. Its skin is soft and smooth, the fleshy part of the fruit is juicy, and has a very sweet and acidulous taste. It contains a great quantity of crystallizable sugar, citric acid and gum.

18. *Pepper* is the berry of the *piper nigrum*. The unripe

berries are *black pepper*, and the ripe berries deprived of their outer skins constitute *white pepper.* Oerstedt detected a matter in this seed, which he called *piperin*, a peculiar vegetable principle. It is composed of piperin $C^{40}H^{22}O^{8}N=340$. An acid, fatty matter, a volatile oil, extractive, gum, starch, bassorin in abundance, a malate, and some other salts.

19. *Cubebs* are the berries of the *piper cubeba*, and are similar in appearance to pepper-corns. They are of an aromatic and acrid taste, and contain a peculiar vegetable principle called *cubebin.*

20. *Cayenne pepper* is the fruit of the *capsicum annuum*, a native of India, but cultivated in the West Indies. The following is the analysis of Braconnot: 100 parts contain of

Starch	9.	Animalized matter	5.0
A very acrid oil	1.9	Citrate of potash	6.0
Wax, with red coloring-matter	0.9	Lignin	67.8
Gum of a peculiar nature	6.0	Muriate & phosphate of potash	3.4
			100.0

The acrid oil gives it its peculiar bitter and burning taste. It has been called *capsicin.* Cayenne is a well-known spice, and is much used in the preparation of Thompsonian nostrums.

21. *Jamaica pepper* (pimento), the fruit of the *myrtus pimento*, resembles black pepper, and is prepared in the same way from the unripe berries. Their odor and taste resemble a mixture of pepper, cinnamon and cloves. The following is the analysis of Bonastre, of 100 parts.

Volatile oil	5.	Resinous matter	3.2
Soft green resin	2.5	Extract containing sugar	8.0
Solid fat oil	1.2	Malic and gallic acids	1.6
Extract containing tannin	39.8	Lignin	16.
Gum	7.2	Ashes containing salts	1.9
Brown coloring-matter	8.8	Moisture	3.
			98.2

22. *Tamarinds* consist of the pulpy matter which fills the pods of the *tamarindus Indica.* It is a well known sweet-meat, brought to this country preserved in sugar. It consists, according to the analysis of Vauquelin, of

Supertartrate of potash	300	Tartaric acid	144
Gum	432	Malic acid	40
Sugar	1152	Feculent matter	2880
Jelly	576	Water	3364
Citric acid	864		9752

23. *Juniper berries* grow on a small shrub (*juniperus communis*) in Scotland. They contain a peculiar volatile oil, which imparts its peculiar flavor to Dutch gin, in the manufacture of which they are highly valued.

24. *Anise* is the seed of a plant (*pimpinella anisum*) cultivated in Spain and Malta. The seeds have a peculiar aromatic smell, a pleasant sweetish taste, and are used in medicine.

25. *Mustard.* There are two species of this plant found in this country; the *sinapis nigra* or black mustard, and the *sinapis alba* or white mustard. The composition of both is similar. They contain a peculiar principle, called *sinapin* ($C^{24}H^{22}O^{7}$ and 2 equivalents of sulphur=268). The white mustard, according to John, is composed as follows: of an acrid, volatile and a yellow fixed oil, brown resin, gum, lignin, albumen, phosphoric acid and salts. Mustard acts as a powerful excitant. Its uses are well known. White mustard has been a celebrated remedy for dispepsy.

26. *Cocoa-nut.* This is the fruit of a species of palm (*cocos nucifera*). The kernel contains a quantity of fixed oil, which is used in India for lamps. The fibres of the outer coat are formed into excellent cordage. It contains within, a milky, sweetish, saline fluid.

27. *Cucumber.* The common cucumber (*cucumis sativus*) is composed of the following substances.

Water	97.13	Phosphate of lime and of potash, phosphoric acid, ammoniacal salt, a malate, sulphate and muriate of potash, and phosphate of iron	0.5
Substances similar to fungin	0·53		
Soluble vegetable albumen	0.13		
Resin	0.04		
Extractive with sugar	1.66		
			100.00

28. *Thorn-apple* (*datura stramonium*) is too well known to need description. It has narcotic properties, similar to belladonna.

29. *Nutmeg* is the fruit of the *myristica moschata*, and is much used as an article for seasoning food. It is a native of the Mollucca Islands. The covering of the nut is called *mace.* It has been analyzed by M. Bonastre, and consists, in 100 parts, of

Fat butyraceous oil	31.6	Acid	0.8
Volatile oil	6.0	Lignin	56.
Starch	2.4	Loss	5.
Gum	1.2		100.

30. *Coffee bean* is the fruit of the *coffæa Arabica*, and is in general use for the manufacture of coffee. The tree is a native of Arabia, but is extensively cultivated, both in the East and West Indies. It contains a peculiar principle called *caffein* (C^4H^2NO=48.5). According to the analysis of Hermann, the coffee bean, from Martinique, contains

Resin	68.	Lignin	11386
Extractive	310.	Loss	12
Gum	144.		1920

31. *Hops* are obtained from the *humulus lupilus*, and are employed extensively in the manufacture of beer and ale. The hop is a dioecious plant, the female alone bearing fruit. It is a valuable plant, and was introduced into England in the reign of Henry the VIII.

32. *Dates* are the fruit of the palm, (*phœnix datilyfera*,) and constitutes an important article of food in several warm countries. It has a sweet taste, and contains a large quantity of sugar.

This catalogue of fruits and seeds, and other products of the vital principle, might be increased; but a sufficient number have been noticed here to give the reader some idea of their number, variety, properties and uses. They are intended chiefly, as a convenient reference to those who may not have access to better sources of information.

There are several other simple bodies contained in vegetables besides oxygen, hydrogen, carbon and nitrogen; but as they do not, by their combinations, form the peculiar products of the vital principle, they are not noticed in this place. They will more properly come under review in the next two sections, which treat of the source and assimilation of the simple substances which enter into the composition of plants. It should also be remarked, that those substances which nourish vegetables, are often derived from organic bodies, and that many compounds are classed as organic, simply because they are derived from organic bodies. But they are the products of *death* or *decay*, not of *life*.

SECT. 2. *Definitions and Descriptions.—Source and assimilation of the Organic Constituents of Plants.*

1. *Humin* is a substance found in the soil. It is composed of carbon, hydrogen and oxygen, and is similar to woody fibre.

In fact it is wood partially decayed. It is insoluble in water, but is converted by the agency of water, air or alkalies, into

2. *Humic acid*, which is identical in composition with it. *Humic acid* is a brownish-black substance, floculent when first precipitated, and soluble in 2,500 times its weight of water, and becomes less and less soluble the longer it is exposed to the air. It is composed, according to Sprengel, of carbon 58., hydrogen 2.10, and oxygen 39.90 in 100 parts. Boullay gives the composition of *geic acid*, which is identical with humic acid. Malagutti gives nearly the same composition.

	Boullay.			*Malagutti.*	
Oxygen	55.70	or 15 atoms.		Oxygen	57.48
Hydrogen	4.81	15 "		Hydrogen	3.76
Carbon	38.49	30 "		Carbon	37.36
	99.37				99.60

Hence its composition may be represented by $C^{30}H^{15}O^{15}$=or about 58 per cent. of humic acid is carbon.

3. *Crenic acid*, from *krene* the Greek word for fountain, is composed, according to the analysis of Hermann, of $C^7H^{16}NO^6$. When pure it is of a yellow color, quite transparent, with no tendency to crystallize. It has no odor, but its taste is sharp, at first acid, and afterwards astringent. When in solution the astringent taste alone can be perceived. It is *excessively soluble in water and alcohol.* It combines with lime, and forms the *crenate of lime*, which is soluble in water, and the *subcrenate* of lime which is insoluble. The *crenates* of potassa, ammonia and soda, resemble extracts of a yellowish color, very soluble in water, and in weak alcohol.

The crenate of magnesia is readily dissolved in water, but the neutral crenate of alumina is insoluble, while the subsalt is soluble. *The crenate of iron* is also soluble in water. Hence, as all these substances are found in the soil, and nearly all are soluble in water, they must enter the organs of plants with that fluid.

4. *Apocrenic acid* is formed from the crenic, by simply exposing the latter to the air. Its composition may be represented thus: $C^{14}H^{14}N^3O^3$. It is a brown extract, possessing a purely astringent taste. It is slightly soluble in water, is readily dissolved in crenic acid, and slowly in alcohol. As the crenic acid always, upon exposure, changes into this acid, the existence of the former appears essential to the production of the latter.

The apocrenates of potassa, ammonia and soda are black, friable masses, and when soluble in water, are of a dark-brown color. Those of lime, magnesia, etc. are of a yellow color, and soluble in water; but the subsalts are insoluble.

5. *Apocrenate of alumina*, when neutral, is insoluble; but soluble when there is an excess of acid. *Apocrenate* of the *protoxide of iron* is soluble, but the salt of the *peroxide* is insoluble in water; hence this acid with its various salts are generally soluble in water to some extent, and must be conveyed into the organs of plants.

6. *Extract of humus and glarin* are brown matters composed mostly of carbon, hydrogen and oxygen. The above substances form the chief ingredients of *vegetable mould*, and pass into each other in the changes which take place in the soil.

When plants are subjected to *ultimate analysis*, that is, resolved into their simple constituents, they are found to be composed of carbon, oxygen, hydrogen and nitrogen, which form the *vegetable proximate principles ;* together with phosphorus, silicon and sulphur ; the alkalies, soda, potassa, ammonia ; the alkaline earths, magnesia, lime and alumina, and the oxides of iron, and of manganese. The four simple substances, which form the proximate principles, are called the *organic*, and the remaining bodies the *inorganic constituents* of plants.

The simple bodies of which vegetables are composed, are, of course, all or nearly all derived from a source *foreign* to the plant ; for although the vital power, may combine these simple elements, so as to form a great variety of different compounds, it cannot *create* a single particle of matter. The view which was formerly taken, that metallic oxides were the products of the vital power, has no foundation, either in fact, or in philosophy. Whence then do plants derive the materials, out of which, their vital functions build up their vegetable structure? In what particular form do they enter the organs of plants, and what are the changes which take place in their assimilation ? These questions have been variously answered, and some things are still matters of controversy. It will be necessary to devote this and the following sections to a full discussion of the theories of those chemists and physiologists, which are best entitled to confidence.

In the present state of our knowledge, it will be more useful to present the arguments *for* and *against* the most favorite theories, and to state the practical deductions which naturally grow out of them.

I. *Carbon.* The most abundant substance in vegetables, is *carbon.* From whence is it derived, and what are the changes which take place in its assimilation ?

History. It has been the general opinion of agricultural writers, that *vegetable mould* or *humus* is the principal source of the *carbon* of plants ; and hence, the cause of the fertility of soils.

Humus or *mould* is a brown substance, easily soluble in alkalies, and but slightly soluble in water. It results from the decomposition of vegetable matter, when subjected to the agency of water and air, but its formation may be promoted by the action of alkalies, alkaline earths, metallic oxides, and in some cases by acids. Chemists have designated this substance by several names ; sometimes including all the decomposed organic matters of the soil under the term *humus* or *geine*, and sometimes only the soluble parts of it. Berzelius, in 1833, divided the organic matters of the soil into *extract of humus*, *geine* and *carbonaceous mould;* and in 1841 he made the following division ; *extract of humus*, *humic acid*, *humin*, *crenic* and *apocrenic acids.* Now the *geine* of 1833 is the *humic acid* of 1841. Dr. Dana calls all the decomposed organic matter of the soil *geine.* This consists of two parts ; that which is decomposed by, or is *soluble* in alkalies, and which is a definite compound, he calls *soluble geine*, and as it exhibits the properties of an acid, *geic acid,* answering to *humic acid;* and that which is *insoluble* in the same solvent, he calls *insoluble geine.* He also admits the existence of *crenic* and *apocrenic* acids.

Dr. C. T. Jackson denies the existence of any such definite compound as *soluble geine*, but makes the substance so called consist of *crenic* and *apocrenic* acids, combined in part, with bases forming in fact a mass of salts.

Liebig disregards all these different substances, and calls the whole *humus* or *humic acid*. This *geine* or *humic* acid of soils, appears to be identical in composition with a substance, noticed by Vauquelin in the bark of the elm, and which is the product of *vitality* called *ulmin*, and *ulmic acid*. It is in fact, elm-gum, or mucillage. It was also called *humic acid*. But Berzelius regards the *ulmic* or *humic acid* of soils, which is the product of decay or death, as different from that which is the product of life. There are also several artificial compounds, which are nearly identical with *humic acid*. "*Ulmin, humic acid, coal of humus* and *humin*," says Liebig, "are names applied to different modifications of *humus*. They are obtained by treating peat, woody fibre, or brown coal with alkalies; by decomposing sugar, starch, or sugar of milk by means of acids; or by exposing alkaline solutions of tannic and gallic acids to the action of the air." The soluble parts he calls *humic acid;* and the insoluble, *humin* or *coal of humus*. Liebig has attempted to show, that these artificial products, although they have received the same name, *humic acid*, are as different in composition, as sugar, acetic acid and resin;* and that there is not the slightest ground for the belief, that any one of them "exists in nature in the form, and endowed with the properties, of the vegetable con-

* Thus the sulphate of potash and saw-dust, when fused form humic acid containing 72 parts of C in 100 (*Peligot*). Turf and brown coal yield an acid containing 58 parts of C in 100 (*Sprengel*). Dilute sulphuric acid and sugar yield 57 parts of C (*Malaguti*). Muriatic acid and sugar or starch yield 64 per cent. of C (*Stein*). Malaguti states, that humic acid contains an equal number of equivalents of oxygen and hydrogen; but according to Sprengel, the oxygen is in excess, and Peligot estimates the excess to be 14 equiv. of oxygen to 6 of hydrogen; but, Hermann makes the *humic acid of soils* to be composed of 58 parts of C, 2.10 of hydrogen, and 39.90 of oxygen.

stituents of mould;" that is, he denies the existence of these substances *in the soil*, and that they exert the slightest influence upon vegetation. But with this exception of Liebig and Raspail, all chemists admit the existence of humic acid in the *soil*. It should be observed further, that the humic acid of soils is *constant* in its composition, while that formed by artificial processes, varies in the proportion of its carbon.

"Once for all," says Dr. Dana, when speaking of the humic acid of soils, "I consider ulmin, humus, geine, ulmic and geic acid *one identical substance*, whether neutral or acid, its constitution ever one and the same, subject to the great law of organic chemistry, that proximate compounds act as simple elements."*

But whatever name we give to this substance, whether we regard it as a definite organic compound in the soil, generally united to oxides, forming in fact a mass of *geates*, or as composed of several acids, which are also combined with similar bases, forming *crenates*, *apocrenates* and *humates*, or whether it is differently constituted; it has heen generally believed to be the source from whence plants derive most of their carbon.

There is one distinguished chemist, however, Liebig, who has lately advocated the opinion, that the *humus* of soil does not yield the "smallest quantity of carbon to plants," and "that the only use of it is, to form a small quantity of carbonic acid, a substance which exists in sufficient abundance in the atmosphere, and from which alone, *all* the carbon is derived." This theory, with others, will now be examined at length.

I *Theory of Liebig*. According to this theory, the only source of the carbon of plants, is carbonic acid, which is found either in the atmosphere, and absorbed by the leaves of plants, or is dissolved in water, and enters by the roots. In both cases, the acid is decomposed in the leaves, by the

* For a full history of this substance, see Dana's Muck Manual, p. 72 seq.

influence of solar light. This theory differs from others, only in supposing, that *all* the carbon of plants is derived from the carbonic acid of the atmosphere. All chemists and vegetable physiologists fully agree, that a large portion of the carbon is thus obtained.

Arguments in support of this theory. Liebig represents *humic acid* or *humus*, as the only substance in the soil, *capable* of yielding carbon to plants; and, as it requires 2500 parts of water to dissolve it, alkalies or alkaline earths must combine with it, to render it soluble and capable of entering the roots. Now this acid is a definite compound, and he attempts therefore, to determine the exact quantity which will combine with the inorganic base, which enter into the composition of vegetables.

1. Suppose that the *humate of lime*, the most abundant salt of humic acid, is the source of the carbon. On the supposition that the lime remains fixed in the vegetable organs, it is found by accurate calculation, that only $\frac{1}{26}$ part of the carbon, actually found in plants, could be introduced in this way.

2. If we calculate the quantity of metallic oxides in wheat straw, and the known quantity of humic acid required to saturate them, we shall find, that the proportion of carbon introduced by this means, will be as 1 to 17, or about $\frac{1}{17}$ part of the carbon which the straw actually contains.

3. Humate of lime, the most soluble of all the salts of humic acid, must first be dissolved in water, one part of which requires 2500 of water for solution. Now if we calculate the quantity of water which falls on a given surface, in one season, and suppose all the water to enter the organs of plants, the humate of lime which it would carry with it, would not yield more than $\frac{1}{12}$ of the quantity of carbon which is found in the corn, grown on the same surface. But only a small part of the water actually enters the roots of plants, and hence,

the quantity of carbon introduced by this means, must be much less.

4. Fertile land produces carbon in the form of *wood, hay, grain,* and other kinds of growth, the bulks of which differ in a remarkable degree, but the quantity of carbon yielded by equal surfaces is quite constant. On the supposition that the land is equally fertile, the weights of forest trees, hay, beet root and rye, growing on an equal surface, are as 2650, 2500, 20,000, 2580; but when these several products are decomposed, the actual quantity of carbon in each is about 100 parts; hence, the quantity of carbon is not affected by manure, as forest lands, meadows and cultivated fields yield the same amount. These facts show that the *humus* of the soil is not the source of the carbon.

Whence then is it derived? It is universally admitted, that humus arises from the decay of plants. No primitive humus, therefore, can have existed, for plants must have preceded the humus.

Now, whence did the first vegetables derive their carbon? and in what form is the carbon contained in the atmosphere? These two questions are easily answered, when we consider, that the atmosphere contains carbon in the form of carbonic acid, in nearly *invariable proportions.* The carbonic acid, amounts, constantly, according to Saussure, to 0.000415 of its volume, or about $\frac{1}{1000}$ part by weight, although several causes are constantly tending to increase it. The respiration of animals throws off immense quantities into the atmosphere. Great quantities are also evolved from volcanic districts and from certain springs. It is liberated from limestone, and other carbonates, by chemical action; and, finally, the process of combustion must very much increase the amount. By this latter process, and by the respiration of animals, oxygen is consumed; but the atmosphere always contains the same proportion of oxygen, why does not the oxygen diminish and the carbonic acid increase? simply because plants absorb the carbonic acid, assimilate the carbon, and yield back the oxygen to the atmosphere, and they must always have done the same.

This remarkable property of plants has been demonstrated in the most satisfactory manner by Priestley and Sennebier. The power of decomposing the acid resides in the leaf, but is exercised only when the leaf is exposed to the light. This power is not dependent upon the connection of the leaf with the stem, as leaves separated from the stalk, and exposed, in an atmosphere of carbonic acid, to the solar light, readily absorb and decompose it; but if the plant is immersed in an alkaline solution, which will prevent the carbon from being assimilated, no oxygen will be emitted. Hence it appears, that the life of plants is connected with that of animals, in a most simple manner, and for a wise and sublime purpose. Plants may live without animals, but animals must have organic matter for their support. Plants purify the air, and furnish an inexhaustible source of oxygen gas.

The only questions now are, whether there is a sufficient quantity of carbonic acid in the atmosphere to supply the wants of plants; and if so, whether it is available?

As to the quantity. We know the exact weight of the whole atmosphere; for every square inch, on the surface of the earth, weighs 15lbs., of which $\frac{1}{1000}$ part by weight is carbonic acid. By this data, the quantity of carbon in the form of carbonic acid amounts to nearly 3000 billions of pounds; a quantity more than the weight of all the plants, and all the strata of mineral and brown coal, which exist upon the earth. This carbon is, therefore, more than adequate for all the purposes for which it is required. The proportional quantity of carbon contained in sea-water,* is still greater.

That this carbon is available to plants, appears from the fact that the winds, moving at the rate of sixty miles per hour,

* 10,000 volumes of sea-water contain 620 volumes of carbonic acid.

are constantly mingling the top and bottom air, and the carbonic acid of the northern regions is thus carried to the tropics, where a luxuriant vegetation liberates the oxygen, and sends it back again towards the poles. The leaves, also, which are the organs of absorption, present a large surface, in contact with which the acid is constantly brought.

5. As the most important function in the life of plants is the separation of oxygen gas, no matter can be considered nutritious, or necessary to the growth of plants, whose composition is similar to, or identical with, the vegetable products. Thus starch, gum and sugar cannot be vegetable food, as their assimilation would take place without the separation of oxygen. Now humus, or decaying woody fibre, contains carbon and the elements of water, without any excess of oxygen; hence it resembles one class of vegetable products, and cannot, therefore, be assimilated and become the source of the carbon.

6. The very nature of decay, that is, of the conversion of wood and vegetable matter into humus, shows that carbonic acid is the only source of the carbon. In the decay of woody fibre, what are the chemical changes which take place? Oxygen is absorbed from the air, and carbonic acid is evolved. The oxygen of the air combines with the hydrogen of the wood, and the carbon and the oxygen of the wood are evolved in the form of carbonic acid. If the oxygen of the air combined with the carbon, so as to produce a genuine combustion, the carbon of the woody fibre would in time be all removed. But the proportion of carbon is greater in humus than in woody fibre; hence it is a process of oxidation, while carbonic acid is *evolved;* but after a while, the attraction of the oxygen for the hydrogen is overcome by the attraction of the carbon for the same substance, and the process of decay ceases. The brown substance which remains is called *mould*, and is the product of the complete decay of woody fibre. Alkalies increase this tendency to decay, and acids retard it.

When the soil is stirred, it facilitates the introduction of oxygen, which also hastens the process. How then does the decaying woody fibre act? Simply by yielding carbonic acid: and when any substance, as stagnant water, or the composition of the soil, arrests the process of decay by excluding the air, then the carbonic acid is not yielded to the roots of plants, and the leaves turn yellow and fall off.

7. Finally, that carbonic acid is the only source of the carbon, appears from the fact, that in the "chemical transformations" which take place in the process of assimilation, the effete, or excrementitious matters, which are thrown out by the roots, contain a quantity of carbon, nearly or quite equal to that which the humus yields in the form of carbonic acid. This matter becomes humus, and is converted into carbonic acid again, in the process of decay. Now when these excretions are added to the carbon, derived from the roots of plants and from their leaves, the quantity annually returned to the soil, must be greater than that which is taken from it. "A soil receives more carbon in this form, than its decaying humus had lost in the form of carbonic acid."—*L.*

From all these facts, it appears evident that humus does not nourish plants by being taken up and assimilated in its unaltered state, but by furnishing a slow and lasting source of carbonic acid. It should be remarked in this connection, that it is only during the period of youth, that plants use even the carbonic acid derived from the humus of the soil. As soon as their organs are sufficiently enlarged, they derive their carbon *wholly* from the atmosphere.

We have been thus particular in giving the leading arguments by which this theory is advocated, because of the boldness and novelty of the views which it contains, and also because it points out the most important source of the carbon of plants; and although it is not true, as we shall show, that carbonic acid is the *only source* of the carbon, this theory will aid us in determining what portion is derived from that source.

Objections to the Theory of Liebig. The arguments by which this theory is supported, are not all well founded; and if they were, they would not prove its truth, but would furnish good reasons for the opposite opinion, that plants derive a part of their carbon from other sources.

1. This theory does not give a correct view of the composition of *humus.* According to the recent analysis of Berzelius, the humus of soils, as we have seen, is composed of humin, extract of humus, humic, crenic and apocrenic acids, and some salts. Dr. C. T. Jackson makes the humus of soils consist of more than twenty substances, of which humic, crenic and apocrenic acids are the most important. These substances are rich in carbon, containing from fifty to sixty per cent. They are rendered soluble in water, by the action of the oxygen of the air and of alkalies; they must therefore enter the roots of plants, and may be decomposed in the vegetable organs, yielding their carbon, oxygen and hydrogen, while the inorganic bases with which they were united, may be returned to the soil as excretory matter. Thus, according to the theory itself, and to other facts, the inorganic bases, which Liebig supposes remain *fixed* in the plant, may be the means of conveying successive portions of carbon into the vegetable organs. In fact the decomposition of salts by the "catalysis of life" is the most important change which takes place in the soil. The bases are thus let loose upon the humus, combine with it, and the salts may again be decomposed. Hence, a part of the carbon must be derived from the humus of the soil.

2. But, on the supposition that no larger quantity of carbon could be introduced, by means of humic acid or humates, than the theory supposes, the conclusion is still unavoidable, that *a part* of the carbon is derived from this source, or else, that large quantities of carbon are taken into the vegetable organs and again rejected, without being decomposed; but in such a case, they must act as poisons, and become a constant source

of injury. Of course, the richer a soil is in humus, the more injurious must its effects be upon the crop!

3. This theory does not give a correct view of the quantity of water in the soil. Rains are by no means the only source of water. All vegetable bodies, according to Liebig, and others, in the process of decay, yield carbonic acid and water. For, although water is decomposed, it is but a small quantity, compared with that which is formed by the union of the oxygen of the air and the hydrogen of the vegetable matter. From this latter source, not noticed by Liebig, a quantity of water is furnished, sufficient to hold in solution a larger quantity of humates, than the theory supposes.

This is a perfect answer to the assertion, that the rains do not furnish a sufficient quantity* of water to hold the humates in solution. In fact, it is highly probable, that the plants, on an acre of soil, take up by their roots and transpire through their leaves, a larger quantity of water, during any given time, than falls during the same time upon an equal surface. But if water dissolves *any portion* of the humates, it must be the means of conveying to the plant a portion of their carbon.

4. This theory entirely overlooks the influence of living plants upon the alkalies in the soil.

The vegetable, in connection with the soil and water, forms a galvanic battery, by which the alkalies are eliminated. These alkalies, coming in contact with *humus* or *geine*, render it soluble. This is a farther means of introducing humates into the organs of plants,† and hence a part of the carbon must be derived from this source.

5. "Vegetable and animal manures," says Berzelius, "become changed, after a while, into crenic, apocrenic and humic acids, in order to supply what has been removed by the

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* See Dana's Muck Manual, p. 225.

† See Dr. Dana's Letter to Prof. Hitchcock, in the Final Report of the Geology of Massachusetts. Also, Appendix to Liebig, 2d edit.

crops, which have been taken from the soil." Hence it would seem, that these substances are the sources of a part at least of the carbon, and that it enters mostly in the form of *humates* (*geates*), *crenates* and *apocrenates*.

6. This theory is inconsistent with itself and with facts. If, as Liebig contends, plants give out to the soil effete matter, mostly composed of carbon, this matter cannot affect the succeeding crop; for if all the carbon is derived from the atmosphere, the excretions will not be absorbed in larger quantities than other matters, especially as they are nearly insoluble. But Liebig and others admit, and experience seems to prove, that the effete matters of one family, are injurious to succeeding crops of the same family, but useful to those of a different race.

On this theory the fertility of soils does not depend, in the slightest degree, upon the quantity of vegetable matter, *the humus* or *geine;* a conclusion which is opposed to all experience on the subject. For it has been observed by every farmer, that vegetable substances are highly promotive of fertility, so much so, that it has long been the effort of farmers to convert their soils into loams by the addition of these substances; that is, by increasing the quantity of *vegetable mould* or humus. A soil rich in humus or geine is generally fertile, one destitute of it is wholly barren; and the degree of fertility, as will be fully shown in a future section, is very much in the ratio of the soluble geine which the soil contains.

According to this theory, a continual course of cropping ought to increase the quantity of carbon in the soil, especially as the soil may be so constituted as to contain but little decaying humus to supply carbonic acid to the roots. But we know that when a field has been cultivated for a long period, and the crops all removed, it will, in the end, be reduced to absolute barrenness; and when we look for the cause, we find the vegetable matter is mostly or quite removed. The effect of manures, therefore, in keeping up the quantity of vegetable mould, and with it, the fertility, proves conclusively, that plants derive their carbon from other sources than carbonic acid. "A seed germinates in a soil in which no vegetable matter exists; it sprouts vigorously, increases then slowly, grows languidly at the expense of the air; and the plant dies stinted or immature."*

6. Finally, it appears upon a general view of the subject, that although carbonic acid is absorbed by the leaves and roots of plants, and is a source of a large quantity of their carbon, yet other substances, rich in carbon, must enter the roots of plants, must be decomposed, and their carbon assimilated.

The fact, that the atmosphere contains carbon in sufficient quantities to supply the whole vegetation of the globe with it, does not prove it the *only* source. The fact, that the atmosphere is not, in time, filled with this acid, does not show that plants must derive *all* their carbon from it, or else its purity would be destroyed. There is a vast ocean of water which is constantly absorbing carbonic acid. Growing vegetables are acknowledged by all, to decompose a large quantity of it, and thus to contribute to the purity of the atmosphere. And this process is truly for a sublime purpose; but yet, the necessity of deriving carbon from the humus of the soil, is not, on this account, wholly dispensed with.

This theory, then, must not be received in the absolute sense, but only as showing, in a strong light, the *principal* source of the carbon of plants; while the nature of humus is such, according to the theory itself, as to furnish abundant ground for the opinion, that a part of the carbon is derived from that source. Although it may be true, that the whole of the carbon was originally derived from the atmosphere, it is not true that any single crop derives the whole, directly, from this source.

* Johnson's Lectures.

The other sources, from which plants derive their carbon, have already been pointed out. The *humus* of the soil is composed mostly, as we have seen, of humic or geic acid, crenic and apocrenic acids. These substances contain large quantities of carbon, generally in the form of salts, which are soluble in water. They must enter the roots with that liquid, and yield their carbon to the plant.

The proportion of carbon derived from the atmosphere, and from other sources, will depend upon the nature and age of the plant; the quantity of food in the soil or the air; climate; quantity of light, and similar circumstances.

We know, by the observations of every day, that fields which are constantly covered with vegetation, such as pastures and wood lands, increase in carbon. They must not only take from the air nearly the whole which enters into their substance, but they must also add to the quantity in the soil, This certainly must be the case in peat swamps, where the vegetable matter accumulates to a depth of several feet. But tillage crops, as appears both from observation and experiment, take more from the soil than they return to it. By the carefully conducted experiments* of Boussingault, the quantity of carbon, which plants derive from the atmosphere during five years' rotation, was about two-thirds of what they contained; but it is evident, that a considerable quantity of carbon in the soil, must pass into the atmosphere in the form of carbonic acid; and hence the quantity obtained from the air, must exceed two-thirds of the whole.†

* The principle, upon which the experiments were conducted, was, to examine for a series of years, the quantity of carbon in the soil before the crop, the quantity in the crop itself, the quantity in the soil after the crop was removed, and the quantity added in manure.

† On the supposition, that two-thirds of the carbon is derived from the atmosphere, and if we allow one ton and a half to be the average quantity of dried produce on an acre of surface, the quantity of carbon would be about 1100 pounds.

If any confidence can be placed in the quantity, which may be conveyed to the vegetable organs, in the form of *humates, crenates* and *apocrenates*, we should infer, that when these latter substances were abundant, more than one third might be introduced by these means; but when not abundant, much less than that proportion of the whole carbon which the plant contains, would be furnished from the soil. So far, then, as the state of our knowledge enables us to come to any just conclusions, the sources of the carbon of plants are,

1. The carbonic acid of the atmosphere, which is the principal source.

2. The humus of the soil, or the humates, crenates and apocrenates, found in vegetable mould.

The precise quantity, from each of these sources, it is difficult to determine, as it will vary with circumstances; hence, we may conclude that plants, like animals, are capable of adapting themselves to their situation, and of obtaining, from one or the other of these sources, the carbon which forms the largest portion of their substance.

Theory of the assimilation of carbon. The changes wrought in the vegetable organs, upon the substances which furnish carbon to plants, are, as yet, mostly matters of theory.

We know, indeed, that carbonic acid and other substances rich in carbon, are absorbed by plants, and that oxygen, nitrogen, and some other gaseous bodies, are exhaled by the leaves and other green parts. But the carbon does not exist in the plant in a pure state, but in combination with oxygen, hydrogen and nitrogen, in definite proportions, forming the *vegetable proximate principles.* How then is the carbon assimilated ?

The process of assimilation may be illustrated by chemical transformations, although the vital power, in its mysterious operations, must be resorted to, in order fully to explain the phenomena. "An organic chemical transformation, is the separation of the elements of one or several combinations, and their reunion into two or several others, which contain the same number of elements, either grouped in another manner or in different proportions."*

"Of two compounds, formed in consequence of such a change, one remains as a component part of the blossom or fruit, while the other is separated by the roots, in the form of excrementitious matter. *No process of nutrition can be conceived to subsist in animals or vegetables without the separation of effete matters.*"*

A transformation must take place, whenever there is a disturbance of the mutual attraction which subsists between the simple elements of bodies. The elements arrange themselves, so as to give rise to new substances, either with or without the separation of one of the elements of the compound. "Hydrocyanic acid and water, for example, contain all the elements of carbonic acid, ammonia, urea, cyanuric acid, cyanilic acid, oxalic acid, formic acid, melam, ammelin, melamin, azulmin, mellon, hydromellonic acid and allantoin."* All these substances may be obtained from hydrocyanic acid and water, by various chemical transformations.

Suppose now, that carbonic, humic and crenic acids, were to meet each other in the vegetable organs, either in the pure state, or in the form of their soluble salts (and they must so meet), their mutual affinities would be disturbed, and their elements arranged, so as to form several, if not all, of the vegetable compounds. Each organ would extract what food was fitted for its sustenance. That is, one vegetable substance being formed, the remaining elements which are not assimilated, would combine together and be rejected at once as effete matter; or by coming in contact with another organ would pass through another transformation, and so continue on, until, being capable of no farther transformations, the matter would be separated from the system by the organs destined for that purpose. Thus, the useless matters rejected

* Liebig.

by one organ, would furnish food for a second and a third. The precise changes which take place, are not so easily detected, although some of them are easily deduced, from the known character of the substances which meet; thus, it is easy to see, that woody fibre may be formed by the union of the carbon of the carbonic acid, with water, while the oxygen of the acid, is separated by the leaves. This process may be expressed thus; thirty-six equivalents of carbon derived from thirty-six equivalents of carbonic acid, combined with twenty-two equivalents of hydrogen and twenty-two of oxygen, derived from twenty-two equivalents of water, form woody fibre, with the separation of seventy-two equivalents of oxygen. The oxygen which is separated, is probably derived from the carbonic acid, as there are just seventy-two equivalents in thirty-six of acid, although a part may be derived from the water.

Such transformations are constantly taking place, during the growth of plants, and the consequence is, that excrementitious matters, of different *kinds*, are thrown off, as unfit to nourish the system. Some of these contain an excess of carbon, others of hydrogen, and others still of nitrogen and oxygen. Some of the matter is gaseous, and is given off by the leaves; some of it is liquid, and is ejected at the roots; while part of the effete matter is solid, and remains in the form of the outer bark. In this respect, there is a striking analogy between animals and vegetables. The kidneys, liver and lungs of animals are organs of excretion. The kidneys separate all those substances, which contain an excess of nitrogen; the liver, those in which carbon is in excess, and the lungs, those in which oxygen and hydrogen are most abundant. The latter also exhale alcohol and the volatile oils, when taken into the system; hence these substances are incapable of assimilation.

In the process of respiration, the oxygen of the inspired air, does not enter into combination with the carbon in the lungs, but combines with the hydrogen of the blood, while the carbonic acid is excreted or thrown off. The nitrogenous substances are thrown out in a liquid form, by the urinary organs, and the solid substances, by the intestinal canal. Hence, nutrition in animal bodies is always attended by excretions.* The same is true of vegetables.

The doctrine of transformations, thus given, may serve to illustrate the general nature of assimilation, so far at least as it can be done on strictly chemical principles. Some, as Liebig would seem to convey the idea, that the agency of the *vital power* is not required in those changes, and that the effect may be *fully* accounted for on chemical principles. But what chemical force, or what law known to chemists, can cause thirty-six equivalents of carbon, twenty-two equivalents of hydrogen, and twenty-two equivalents of oxygen, to combine and form woody fibre? We never see such compounds formed, unless it be in the vegetable or animal organs; and this single fact shows conclusively, that some other power than *affinity* is at work to form such combinations.

We see no reason for rejecting the theory, that the vital power of the plant may act by its catalytic force, and decompose bodies which are external to the roots, causing one or more of their elements to enter their organs, and to combine with substances already introduced, or previously formed. Such a view is rendered highly probable, when we consider the fact, that the living plant is a most powerful agent in decomposing the soil, and obtaining the alkali which its wants may require. Life is doubtless a powerful *catalytic* force in producing the transformations which attend the process of assimilation.

II. *Source of the Hydrogen of Plants.* The source of the hydrogen of plants is easily determined, because there are but few substances which contain it in sufficient quantities to supply the wants of vegetation. The chief sources of the hydrogen are the following.

* Some represent the change to be a process of real combustion. Others believe, that the absorbed oxygen unites with the carbon in the course of the circulation.

1. *Water*, which is composed of eight parts of oxygen and one of hydrogen. Water pervades the atmosphere in the form of vapor, is deposited in dew or rain, and absorbed by the leaves of plants. It is also taken in by the roots, and forms a large portion of the sap. When we call to mind the fact of its remarkable tendency to pass through transformations, there can be no doubt, but that it furnishes the largest portion of the hydrogen of plants.

2. *Ammonia* is another substance which contains hydrogen. It is always present in fermenting manures, and in the atmosphere. It must, like water, be absorbed by the leaves of plants, and by their roots; and as it is similar to water in the facility with which it is decomposed, it must furnish hydrogen to the vegetable products. Hence one reason for its powerful effects upon vegetation.

3. *Light carbureted hydrogen* is found in the atmosphere and in the soil, and may be the source of a part of the hydrogen of plants; although it is doubtful, whether they draw upon this source, when there are at hand, more abundant and far better sources. It may, however, be decomposed in the air by electric discharges, and resolved into carbonic acid and water.

4. *Geine* or *humus* of soils contains hydrogen, in the form of humic, crenic and apocrenic acids. These substances enter the organs of plants, and may yield a large portion of the hydrogen. Liebig derives the hydrogen wholly from water.

III. *Source of the Oxygen of Plants.* Oxygen may be derived from several sources.

1. The atmosphere contains twenty-one parts of oxygen in one hundred, and as the leaves of plants are known to absorb it (p. 75), they obtain a part of their oxygen from this inexhaustible source.

2. *Water* contains eight parts in nine of oxygen. This is absorbed both by the leaves and roots of plants in large quantities, and is doubtless the principal source of the oxygen, as well as the hydrogen of vegetable bodies.

3. *Carbonic acid* contains sixteen parts in twenty-two of oxygen, and is a further source of this substance.

4. *Geine* or *humus* contains oxygen, which in the processes of vegetation, is brought into contact with the vegetable organs, and may thus be the source of a portion of the oxygen which plants contain.

5. *Nitric acid* may be still another source, and perhaps several other acids, as the carbonic, phosphoric and sulphuric, which are known to exist in all soils.

IV. *Theory of the Assimilation of Oxygen and of Hydrogen.* Woody fibre, which is the solid part of plants, and is the most abundant of the products of vegetables, is composed of carbon, with oxygen and hydrogen in the proportions to form water; that is, if the hydrogen and oxygen were to combine, water would be formed and carbon left in a free state; or the composition may be represented by the elements of carbonic acid, with a certain quantity of hydrogen.

Now the wood may be formed by the decomposition of carbonic acid; the carbon uniting with the elements of water, and the oxygen escaping as effete matter; or, what is more probable, the carbonic acid may combine with the hydrogen of the decomposed water, while the oxygen of the water escapes. In either case, the quantity of oxygen separated would be exactly the same.

But there are other compounds (as the acids), in which oxygen is in excess; in the process of their formation, therefore, less oxygen would be separated. In case oxygen is in less quantity than in the relative proportion to form water, as it is in alkalies and neutral substances, such as starch, sugar, wax and all resinous bodies, then, in the processes of assimilation, much more oxygen would be separated. Such substances yield a larger quantity, or all of the oxygen, both of the carbonic acid and of the water.* If this is a true rep-

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* The following table of Liebig, illustrates still further the changes

resentation of the changes which actually take place in the assimilation of oxygen and hydrogen, it proves conclusively that the *vital power* is capable of reversing chemical laws. For this process differs entirely from ordinary chemical combinations; thus, for example, when carbonic acid, zinc and water are mingled, hydrogen is separated; but in the process of vegetation, *oxygen* is separated from the living plant, and given back to the atmosphere.

In the process of decay, oxygen is returned to the atmosphere in the form of carbonic acid, and is absorbed from the air to form water; hence, the process of nutrition and decay are exactly opposite.

This theory serves rather to *illustrate* the nature of the changes, than to point out the exact changes which take place. In a similar way, it might be shown what changes may take place, when other substances containing oxygen and hydrogen are taken into the vegetable organs. It is there-

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effected in assimilation, on the supposition that the carbon is derived from carbonic acid, and the oxygen and hydrogen from the water.

36 eq. carbonic acid and 36 eq. hydrogen derived from 36 eq. water } = *Sugar*,

with the separation of 72 eq. oxygen.

36 eq. carbonic acid and 30 eq. hydrogen derived from 30 eq. water } = *Starch*,

with the separation of 72 eq. oxygen.

36 eq. carbonic acid and 16 eq. hydrogen derived from 16 eq. water } = *Tannic Acid*,

with the separation of 64 eq. oxygen.

36 eq. carbonic acid and 18 eq. hydrogen derived from 18 eq. water } = *Tartaric Acid*,

with the separation of 45 eq. oxygen.

36 eq. carbonic acid and 18 eq. hydrogen derived from 18 eq. water } = *Malic Acid*,

with the separation of 54 eq. oxygen.

36 eq. carbonic acid and 24 eq. hydrogen derived from 24 eq. water } = *Oil of Turpentine*.

with the separation of 84 eq. oxygen.

fore highly probable, that plants derive their oxygen and hydrogen, as well as their carbon, from several sources; and that these two substances enter the vegetable organs in the form of water; of geine or humic, crenic and apocrenic acids; of ammonia; of common air; and, probably, of several acids.

V. *Source and Assimilation of the Nitrogen of Plants.* It was formerly supposed, that nitrogen existed in only a few plants, but it is now established that it exists in all. "It exists in every part of the vegetable structure."* The quantity, however, is very small, compared with the other ingredients of the vegetable principles. Hay, dried at 240° F., contains but $1\frac{1}{2}$, oats $2\frac{1}{5}$, and potatoes $1\frac{1}{5}$ per cent. In the ordinary state in which these substances are found, they must contain a much less quantity.

This quantity is small only in comparison with the other organic constituents, for if we calculate the quantity of nitrogen in an average crop of hay and grain grown on three hundred acres of land, it will amount to eight tons.†

This relatively small, but absolutely large quantity of nitrogen is of the highest importance to vegetation. In fact the value of manure has been estimated by its power of yielding nitrogen in the form of ammonia.‡ The body which exists in the smallest quantity in the vegetable products, is just as necessary to their formation, as that which is most abundant. It has been due to a neglect of this principle that so little effort has, as yet, been made to supply plants directly with this substance. Whence, then, do plants derive their nitrogen? The following are the principal sources.

* Liebig.

† A ton of hay contains about 30 lbs. of nitrogen; but the quantity depends very much upon the kind of crop. Red clover contains double the quantity of nitrogen which common hay does; hence, an acre yielding three tons would require 180 lbs. of nitrogen.

‡ Dana.

1. *The atmosphere* contains seventy-nine parts of nitrogen in one hundred, and as it is thus brought into direct contact with the organs of plants, either as a gas, or dissolved in water, it must be absorbed. Hence some have supposed it possible, that a part of that found in vegetable bodies is derived from that source.* But the nitrogen of the air possesses such inert and indifferent properties, as to render it nearly certain, that it is not assimilated directly; although we cannot say what the vital power may effect. It is probable, however, that nitrogen enters plants in some of its combinations. The question whether it came originally from the atmosphere, is quite different from the one now under consideration—the immediate source of it.

2. *Ammonia*, as we have seen p. 81, is produced in considerable abundance. It must be brought into contact with the leaves and roots of plants, and enter into their organs. It is composed of fourteen parts of nitrogen and three of hydrogen. That plants derive a part of their nitrogen from it, appears exceedingly probable from the following considerations.

(1) Ammonia is found in the sap of trees, and in the juices of all vegetables. "The products of the distillation of flowers, herbs and roots, with water, and all extracts of plants made for medicinal purposes, contain ammonia. Ammonia exists in every part of plants, in the roots (as in beet-root), in the stem of the maple-tree, and in all blossoms and fruit in an unripe condition."† In these cases ammonia may possibly be formed by the living power, or it may be the effete matter arising from transformations; but that such is the fact is extremely doubtful.

(2) That ammonia yields nitrogen to plants, is highly probable from the action of animal manures. Gluten is a substance containing the largest quantity of nitrogen in wheat, rye and barley, and is found in different proportions. The more animal manure there is employed in the cultivation of these grains,

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* Johnson. † Liebig.

the greater is the proportion of gluten which they contain. Now animal manures derive their special efficacy from the ammonia they produce; and it is found, that the proportion of gluten depends upon the capacity of the manure to form it. Thus, putrid urine and human excrements will produce much more ammonia than cow-dung or vegetable matter; and hence their peculiar efficacy. The guano, which forms a stratum of sixty or eighty feet in thickness in the South Sea Islands, and which is composed of the excrements of sea fowls, owes its fertile properties, in part, to the large quantity of ammonia which it contains. This manure is an article of commerce, and is placed on the barren soils of Peru, where it produces the most surprising effects. It is composed mostly of urate, phosphate, oxalate and carbonate of ammonia, with a few earthy salts.

Human urine contains nitrogen, in the phosphates and in the *urea;* the latter, by putrefaction, is converted into carbonate of ammonia. Now it is well established, that human urine is the most powerful manure for those *vegetables* which contain a large quantity of nitrogen. The urine of herbiferous animals contains hippuric acid, a substance which is easily decomposed into benzoic acid and ammonia.

(3) The powerful influence of the salts of ammonia, is partly accounted for on the supposition, that they yield nitrogen to plants. The *kind* of influence they exert gives force to this position; for the carbonate and sulphate of ammonia increase the quantity of vegetable products, which require the largest quantity of nitrogen; that is, the gluten and vegetable albumen.

Ammonia, in cool countries, is the last product of the putrefaction of animal bodies. A generation of a thousand millions of men are renewed every thirty years, and thousands of animals cease to live, and are produced in a much shorter period, whence the nitrogen they contained during life? All animal bodies yield ammonia to the atmosphere, hence it must always exist in rain and snow water. It is the simplest of the compounds of nitrogen. Nitrogen has for hydrogen the most powerful affinity. It is capable of being held in solution in water, and readily enters into combination with carbonic, sulphuric and muriatic acids, and by all these means it becomes fixed in the soil. A certain portion of the ammonia which falls in rain water evaporates, but some of it must enter the organs of plants, and by entering into new combinations in the different organs, produces albumen, gluten, quinine, morphia, cyanogen, and a number of other compounds containing nitrogen.

(5) Finally, if we add to these considerations the fact, that ammonia is found in the atmosphere, that it is constantly produced in the soil, and must enter the organs of plants, where, owing to its easy decomposition, its nitrogen must be assimilated, it becomes certain that it yields nitrogen in the processes of nutrition.

The quantity of nitrogen which plants derive from this source cannot be determined. Liebig attempts to prove, that ammonia is the only source of the nitrogen. He also attempts to explain the utility of gypsum, burned clay, powdered charcoal and humus, on the principle that these substances absorb ammonia from the atmosphere, and fix it in the soil. The carbonate of ammonia, which is diffused through the soil and dissolved in water, is decomposed by the gypsum,* and the resulting sulphate of ammonia yields its nitrogen to the plant as its wants demand. As water is necessary to the decomposition of the carbonate by the gypsum, its influence is not observed on dry fields. The other substances mentioned, act by absorption, condensing the ammonia in their pores. The arguments brought in favor of this theory, are not all of them well founded; and if they were, would not prove it

* One bushel of plaster, on this theory, would fix a quantity of ammonia, equal to 6250 pounds of horse urine, and every pound of nitrogen would produce 100 pounds of hay or grain.

true. Thus, for example, it is asserted, that the quantity of nitrogen removed from a well conducted farm, in the form of cattle and grain, must be greater than that returned in the excrements. But Dana has shown, by direct experiment, that the quantity of nitrogen in the excrements of animals, is nearly double* that found in the food, and hence the quantity returned to the soil is constantly increasing.

The fact that ammonia is found in the atmosphere, that it results from the putrefaction of animal bodies, and that it is found in the sap of trees, does not prove that plants derive *all* their nitrogen from it.

But one of the strongest objections to this theory, is the fact, that in warm climates, where vegetation is most flourishing, the process of putrefaction in animal bodies, produces nitric acid, instead of ammonia; hence this latter substance will be found in the least abundance, where the largest quantity is needed, and where it is actually consumed, if this theory is true. "No conclusion," says Liebig, "can then have a better foundation than this, that it is the ammonia of the atmosphere, which funishes nitrogen to plants;" and we may add, no conclusion is better established than this, that ammonia does not furnish plants with the *whole* of their nitrogen.

Whatever reasons there may be for rejecting the theory which derives all the carbon, oxygen and hydrogen of plants from carbonic acid and water, we have equally good reasons for the belief, that ammonia does not furnish plants with all the nitrogen which they contain.

"If it be true," says Daubeny, "as Liebig has endeavored to establish, that plants obtain everything, except their alkaline and earthy constituents, from the atmosphere, what, it may be asked, becomes of the theory that attributes the *unfitness* of a soil for yielding several successive crops of the same plant, to the excretions given out by its roots? For if

* Dana's Muck Manual, p 136.

plants receive the whole of their volatizable ingredients from the atmosphere, these excrementitious matters, being composed chiefly of carbon, hydrogen and oxygen, will not be absorbed, and *therefore cannot affect the succeeding crop*."

If the theory is true, which derives all the organic constituents from carbonic acid, ammonia and water, a plant ought to grow in a purely earthy soil, when supplied with ammonia. But no instance has been produced, and it is yet doubtful, whether the experiment would succeed if tried.

The forms in which ammonia enters the organs of plants, are probably various. It may enter uncombined, simply dissolved in water, and be assimilated in a manner similar to oxygen, carbon and hydrogen, p.156. But it probably enters as a salt, that is, in combination with acids. Dr. C. T. Jackson supposes, that "the carbonate of ammonia acts upon the organic matters of the soil, and renders the organic acids neutral and soluble ; decomposes and renders inert, noxious, metallic salts and other compounds." Dr. Dana supposes, that ammonia combines with the geine to form a soluble compound, and also acts by its presence to convert vegetable matters into geine. In either case, it would be introduced into the organs of plants, and its nitrogen assimilated.

It has been supposed by some, that the powerful influence of ammonia was due to its stimulating properties, but others have doubted such influence; among the latter is Liebig, and among the former, Berzelius. The influence of light, heat and electricity would lead to the opinion, that the vital power of plants is capable of being excited, in a manner analogous to that of animals.

If plants do not derive all their nitrogen from ammonia, what other sources are there from which it can be derived ? We have already observed, that the decomposition of vegetable matters forms,

3. *Geine* or *humus*, which may be a further source of nitrogen. Humus consists of humic, crenic and apocrenic acids.

Humic acid is composed of hydrogen, oxygen and carbon. Crenic acid is composed, according to Hermann, of forty-two parts by weight of carbon, sixteen of hydrogen, fourteen of nitrogen, forty-eight of oxygen. Apocrenic acid is composed of eighty-four parts of carbon, fourteen of hydrogen, forty-two of nitrogen, and twenty-four of oxygen. These latter acids are soluble in water, even when combined with bases, and contain a quantity of nitrogen, which must enter the organs of plants. We have then, only to suppose similar organic transformations, in order that their nitrogen may be assimilated to the vegetable organs. As a part of the carbon is derived from the soil, so a part, at least, of the nitrogen may be derived from the same source.

The influence of crenate of lime (which is sometimes found in the sub-soil) upon clover, favors the idea, that it furnishes a quantity of the nitrogen to seeds, fruits, and other parts of vegetables; for it is found that clover contains nearly double the quantity of nitrogen which is found in many other grasses.

4. *Nitric acid.* The putrefaction of animal bodies, yields large quantities of nitric acid, especially by the fermentation of manures. This acid combines with potash, soda and ammonia, to form salts, which are found, more or less abundant, in all fermented manures. The salts are soluble in water, and must enter the vegetable organs. The acid is composed of fourteen parts of nitrogen and forty of oxygen. Here, then, is another source of the nitrogen of plants. That plants derive a part, at least, of their nitrogen from this source, is proved by the most incontestable facts.

Daubeny has shown, that nitrate of soda, placed upon lands sown with wheat, increased the gluten of the wheat 4.25 per cent., and the albumeni 0.75 per cent. The gluten and albumen contain great quantities of nitrogen, and will be abundant in the seed, in proportion to the proper supply of matters from which they may obtain it. Whence did they

x Albumen

obtain this additional supply of nitrogen, but from the nitric acid? Nitrate of potash produced a similar effect. It is well known what a powerful effect salts of nitric acid, especially salt-petre or nitre, have upon the growth of vegetables. This influence must be due to the nitrogen which is furnished to the gluten, vegetable albumen, and other products of the vital power.

Upon the whole, then, it is highly probable, that plants derive their nitrogen from ammonia, crenic, apocrenic and nitric acids, and that vegetation will be abundant in proportion as these substances are supplied to the roots of plants. They are not, however, introduced in their pure state, but are combined with inorganic bases, in the form of salts, and are decomposed, and their elements assimilated by chemical and vital forces.*

But whatever theories we may form on this subject, upon the source and assimilation of the carbon, hydrogen, oxygen and nitrogen of plants, one thing is certain, that the farmer must supply vegetable and animal manures which contain these elements, or the carbonic acid, water and ammonia of the atmosphere, will not be gathered into the form of vegetable productions. The necessity of supplying the soil with manure, cannot be set aside, by any theories of the source from which plants derive their support; and the best theory is that which shall best explain the facts, and point out the most direct and efficient means for increasing the quantity and quality of the productions of the farm. And we believe it will be found in the end, that plants derive their carbon, hydrogen, oxygen and nitrogen from the several sources named, and that they are endowed with the power of adapting themselves to circumstances, so as to select a greater or less quantity from each source; but that one alone will not support

* Since writing the above, I have received two works, Johnson's Lectures, and Dana's Muck Manual, which substantiate the views given in the text.

their organs in a vigorous state of growth, and enable them to attain their highest perfection.

Sect. 4. *Definitions.—Source and Assimilation of the inorganic Constituents of Plants.*

Potash or *potassa* ($KO=47.15$) is composed of the metal potassium and oxygen, one equivalent of each; of course its combining number is $8+39=47$. This substance is well known. It is found in all plants. It is a solid, easily soluble in water, caustic to the taste, eminently alkaline in all it properties and relations.

Carbonates of potassa are known to us under the name of *pot* and *pearl-ashes*, and *saleratus*. *The nitrate of potassa* is known as *nitre* and *salt-petre*. All the *salts* of this alkali are useful substances.

Soda ($NaO.31.3$) is an alkali similar to potassa. It is composed of 8 parts of oxygen, and 23.3 of the metal sodium; hence its equivalent is 31.3 and its symbol is NaO. It is a white or gray solid, very soluble in water, caustic to the taste, and, combined with acids, forms a large class of salts.

The nitrate of soda, called *cubic nitre*, is similar in its *chemical properties* to nitrate of potassa. The carbonate of soda is well known, as the substance used for soda powders. The sulphate of soda is the well known substance *Glauber's salts.*

Common salt is a *chloride of sodium*, but when it is dissolved in water, or when the chlorine is removed, the metal sodium immediately combines with oxygen, if water is present, and forms *soda.* The chlorine unites with the hydrogen of the water, and forms muriatic acid; these may then combine, and form *hydrochlorate of soda.*

Magnesia ($MgO.20.7$) is a white powder, of an earthy appearance, known in the shops as *calcined* magnesia. It is composed of a peculiar metal, magnesium, 12.7 parts by weight, and 8 parts of oxygen. Its symbol is MgO. It is very infusible and slightly soluble in water, requiring 5142 times its weight of water, at 60° F., and 36,000 of boiling water to dissolve it. When exposed to the air, it absorbs carbonic acid and is converted into *the carbonate of magnesia*, also a white powder, very insoluble in water. *Phosphate* of magnesia is a compound of phosphoric acid and magnesia, and has not been fully examined. Sulphate of magnesia is the common *Epsom salts.*

Lime is composed of the white metal, calcium 20.5 parts, and 8 parts of oxygen. It is a *protoxide of calcium*, and is thus represented, $CaO.=28.5$. Lime is a grayish white solid, caustic, acrid and alkaline to the taste. It has a strong affinity for water, with which it combines, attended with the evolution of much light and heat, and forms a bulky hydrate, called *slacked lime*. It has a strong affinity also for several acids, with which it combines. *The carbonate of lime* is the common limestone and marble. *Sulphate of lime* is gypsum, or plaster of Paris. *Phosphate of lime* is the substance which forms the bones of animals, and exists in the mineral *apatite*.

Alumina is composed of 27.4 parts of aluminium, and 24 parts of oxygen. Its composition is thus represented. Al^2O^3 51.4. It is an inodorous, tasteless substance, insoluble in water, possessing the properties, both of an acid, and of an alkali. When moistened, it forms a ductile mass, and, when combined with silicic acid, forms clay. It is the base of all kinds of pottery.

Oxides of iron. There are at least two oxides of iron. The *protoxide* is composed of twenty-eight parts of iron and eight of oxygen, and is represented by $FeO=36$. It has a dark blue color, and is magnetic. It is so combustible as to take fire, sometimes, in the open air, by which it becomes converted into the

Peroxide of iron which may be represented by $Fe^2O^3=80$. This is the *red hemetite* of mineralogists. It is a brownish-red substance, easily thrown down from a solution of its salts, by pure alkalies. Both of the oxides combine with several acids, and form a numerous class of salts. The sulphate of the protoxide is known as *copperas*. The carbonate of the protoxide exists in most chalybeate mineral waters.

Oxides of manganese. There are several oxides of manganese. The principal one is the

Peroxide of manganese, which is composed of 27.7 parts of manganese (Mn) and 16 parts of oxygen. The symbol is $MnO^2=43.7$. This oxide occurs in black earthy masses, and is not affected by exposure to the air or water. It combines with several acids and forms *salts*.

Silicic acid is composed of 22.5 parts of silicon and 24 parts of oxygen ($SiO^3=46.5$). It is best known in the form of sand, rock-crystal, quartz and flint. It is a tasteless, very infusible and insoluble substance; and although it is not acid by the ordinary chemical tests, it is the most powerful of acids, forming a large class of salts. It is usual, however, to call the compounds of silicic acid with bases, *silicates*, and the compounds of other acids with the same bases, *salts*.

Hydrochloric acid is composed of one equivalent of chlorine, 35.42, and one of hydrogen, 1=36.42. (HCl.) This acid, in its pure state, has very acrid and caustic properties. It is commonly called *muriatic acid*, because obtained from sea salt. Its principle salt is hydrochlorate of ammonia, known as *sal ammoniac*.

Sulphuric acid, a compound of sixteen parts of sulphur and forty of oxygen, is an oily liquid well known as *oil of vitriol.*

Phosphoric acid is composed of two equivalents of phosphorus, 31.4, and 5 of oxygen, 40=71.4 (symbol P^2O^5). This acid resembles snow or ice. It is intensely sour, and combines with a number of alkalies and alkaline earths, forming a class of salts called *phosphates*. Phosphate of lime is the principal substance in the bones of animals.

Nitric acid has been described, p. 48.

Ismorphism is a term used to designate the fact, that bodies of very different chemical constitution, may assume the same crystalline form, and may displace each other in any compound. When this is the case, that is, when one body is substituted for another, there is not an equal, but an equivalent proportion; thus, when soda is substituted for potassa, thirty-one parts of the former take the place of forty-seven of the latter.

As plants uniformly contain several *inorganic* bodies, we infer, that these substances are necessary for the formation of particular organs. For although the inorganic constituents of plants may vary according to the soil in which the plant grows, a certain number of them is absolutely essential to its development. The principal of these inorganic substances are potash, soda, magnesia, lime, alumina, and oxides of iron and of manganese, which are the inorganic bases, and are generally combined with silicic, hydrochloric, sulphuric, phosphoric, carbonic and nitric acids.

The inorganic bases of plants vary with the nature of the soil. De Saussure and Berthier found magnesia in the ashes of a pine tree, growing at Mont Breven, but none in the ashes of the same species of tree from Mont La Salle. The potash and lime also varied in the two localities. This is accounted for by the fact, that one *inorganic* base may be substituted for another, in an *isomorphous proportion.* If, therefore, there is not in a soil that inorganic base which the plant most likes, it will take up a quantity of some other base. There is, however, some inorganic base, which a species of plants prefers to any other, and if that is entirely absent, in some cases the plant will be imperfect or fail to grow altogether, while in others it will be diminished in some of its products. As these bases are combined with *inorganic*, and also with *organic* acids, and as it is only with the latter that substitutions can be made, when one base is substituted for another, a different quantity will be employed, because one equivalent of base must be substituted to saturate the acid, and the combining ratios differ in different bases. But still there is a remarkable law in reference to the quantity of *metallic oxides* or inorganic bases in all these substitutions, the quantity of oxygen is exactly the same; that is, there is an equal number of equivalents of metallic oxides, whatever substitution may be made. Hence, if the soil does not contain one kind of base, it is not on that account barren, but another may supply its place. But notwithstanding this fact, some bases exert a *better influence* upon the development of plants than others. For example, phosphate of magnesia, in combination with ammonia, is found invariably in the seeds of all kinds of grasses. It is contained in the outer, horny husk, and is introduced into the bread with the flour, although the bran contains the larger quantity of it. Hence, this substance is necessary to the perfect development of the grasses and grains. It would also be next to impossible to raise wheat without potash.

There are, moreover, certain species of plants, which require certain alkalies for their growth; such as the sea-plants, which require soda, iodine, or some substance yielded by the sea, as common salt. Such plants will follow the salt water, wherever it is found. If salt-works are opened in the interior of a country, the sea-weeds will find the spot, and migrate to it.

The absolute necessity of inorganic bases to the perfect development of plants, is shown by the fact, that each species of plant produces organic acids, as the acetic, tartaric, malic, etc. These acids are united with bases, either organic or inorganic, and the latter is the case, in most instances. The quantity of these acids can be accurately ascertained in each species of plant; and as their power of saturation is known, the quantity of inorganic bases may be accurately deduced. It must always bear an exact ratio to the organic acids. The quantity of these acids varies according to the nature of the soil, in order to suit the different organic bases.

As the roots of plants, like a sponge, imbibe from the soil whatever substances* are held in solution by water, it is evident, that many of the inorganic bases and other matters will be introduced into the organs of the plants, which cannot be assimilated. These substances are again returned to the soil. This process has been inferred from observation. From the nature of the case, we have a strong presumption in favor of its truth. It may, at least, explain very many phenomena of vegetation. Macaire Princep has shown by experiment, that plants made to vegetate with their roots in a weak solution of acetate of lead (sugar of lead), and then in rain-water, yield back *all the lead* absorbed. So, also, when a plant is sprinkled with nitrate of strontia, it will absorb it by the leaves, but return it all to the soil; hence, we may color a plant with various substances;† but, after a

* The roots do appear to possess some power of discrimination, as they will imbibe different quantities of substances which are presented.

† "When the soil, in which a white hyacinth is growing in a state

while, the coloring-matter will all be returned to the soil. When, therefore, a plant has not a sufficient quantity of its appropriate alkali, it will take up some other, but may return it to the soil, when that alkali is supplied; hence, the importance of supplying the appropriate alkalies and alkaline earths, for the perfect development of every species of plants.

The source of the inorganic constituents of plants, is a point much more easy to determine, than the particular form and mode of their introduction into the organs of plants, and of their assimilation.

1. *Potassa.* Whence do plants derive their potash? This question is easily answered. The rocks contain large quantities of potash, locked up in the feldspar. Granite rocks, such as exist abundantly in New England, contain about seven per cent. of potash, in the form of a *silicate,* that is, united with *silicic acid.* This potash is eliminated by the action of the air, and by carbonic acid; but growing plants possess the power of decomposing the rocks, and of obtaining it in much larger quantities. This is proved by the fact, that plants growing in a glass vessel, will decompose the glass, to obtain the potash which enters into its composition.

The quantity of potash in a soil, is sufficient to sustain most plants for an indefinite period of time. We might almost say, that it is inexhaustible; for pine plain soil of six inches in depth, contains, per acre, thirty-six tons of potash, and a ton and a half of lime. Some plants, however, such as wheat and tobacco, by being planted upon the same soil for a series of years, will exhaust the potash to such an extent, that a change of crops must be resorted to, to restore fertility. There may be some cases, in which minerals be-

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of blossom, is sprinkled with the juice of the Phytolaca decandra (American nightshade), the white blossoms assume, in one or two hours, a red color, which again disappears after a few days under the influence of sunshine, and they become white and colorless as before."—L.

come wholly decomposed; and, when that is the case, the soil becomes absolutely barren, and nothing can restore fertility but the addition of alkalies and gravel; hence the necessity and utility of a rotation of crops; for when all the potash has been removed from the soil by one family of plants, other plants may be substituted, which do not require this alkali for their growth.

In other cases, *free* alkali is needed. Hence the effect of ploughing in green crops, and the utility of fallows. The growing plant eliminates the potash from the feldspar,* and it is then turned into the soil and is ready to be applied to future crops.

All kinds of grain contain, in the outer part of their leaves and stalks, a large quantity of silicate of *potash*, which must be derived from the soil. If now we increase the amount of grass or grain by means of gypsum, a larger quantity of potash will be eliminated, and the free alkali will be carried off, so that in a short time, the crop will be diminished, and either a fallow or some other means must be resorted to, to restore that alkali.

The planters of Virginia, according to Liebig, exhausted their soils by cultivating for a century in succession, tobacco and wheat on the same land without manure. By this process, twelve hundred pounds of alkalies were in the course of one hundred years, abstracted from every acre of soil. Thus these lands were nearly deprived of alkali, and are now barren wastes. Hence the necessity of returning the

* There is not much danger that the alkali will be exhausted by this process. The quantity contained in the rocks, is almost inexhaustible, compared with that taken up by plants; for it is found, that the wheat straw, grown on an acre, takes up only twenty-two pounds of potash, and the quantity in the soil would be sufficient for the straw, during a period of three thousand years. The quantity of potash on an acre of *granitic rock* six inches in depth varies from ninety to one hundred and twenty tons, but a far less quantity is found in the same depth of soil.

potash to the soil, in the vegetable, animal and saline manures. If no vegetable and animal matters are added, a constant course of cropping will extract the free alkalies, and however rich the soil may be in humus, plants will not flourish.

The form in which potash enters the organs of plants, and the mode of assimilation, is a matter of theory. It exists in the form of a *silicate*, in ashes, in feldspar and in manures. It is possible that it is dissolved in water and thus conveyed to the roots of plants. It is also found in combination with organic acids. If it were introduced then, in the form of an oxide dissolved in water, it would combine with the organic acids in the plant, and form the vegetable compounds in which it is found. It may be introduced in combination with humic, crenic and apocrenic acids. But the most probable theory is, that potash is combined with nitric, or some of the inorganic acids, and introduced as a salt; that it is decomposed by the organic acids in the plant, and the acid, either sent out to act upon the silicates and obtain more alkali, or decomposed and its elements assimilated.

2. *Soda.* The source and the assimilation of soda is similar to that of potash. The rocks which supply soda to plants are very few. It is obtained from the sea or salt water; hence, plants containing this alkali in the greatest abundance, are found near the sea or salt springs. Common salt is a chloride of sodium, and forms soda in the form of hydrochlorate of soda by the decomposition of the salt and the water. Now a small quantity of salt is evaporated from salt water,* is carried inland, and becomes one source of the soda of plants; hence the useful effects of salt upon some soils, and for particular crops.

3. *Magnesia.* Magnesia is also derived from the rocks,

* Liebig, p. 192.

and is much more abundant than soda.* It is contained in feldspar and mica, two ingredients of all granitic soils, also in hornblende, but especially in serpentine. The latter rock contains from forty to forty-four per cent. Hence it is an ingredient of all soils, and is either eliminated by the growing plants, or by the acids in the soil. The phosphate of magnesia, as we have seen, is an invariable constituent in all kinds of grass. This alkali may, however, be extracted from the soil, and must be returned by animal and vegetable manures.

Theory of assimilation. Magnesia may enter the organs of the plant, as a *phosphate*. But that plants should assimilate bodies just as they are received into their organs, is contrary to the general doctrine. It unites with several acids and is probably introduced in several forms. In the transformations which take place, the phosphoric acid may be formed, and combine with the magnesia in the act of assimilation.

4. *Lime.* Lime is found in the ashes of most plants, and is derived from the granitic rocks, and from the carbonate and sulphate of lime, two very abundant substances in nature. The quantity contained in the soils of New England is very small, being less than three per cent. Hence, lime is added to most soils with the highest benefit, either as plaster, marl or air-slacked lime, which latter has become partly carbonated.

Theory of assimilation. The mode by which this is introduced into the organs of plants, is probably in the form of *geate*, or *crenate* and *humate* of lime,† a substance always found in the humus of soils.

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* Granitic rocks contain from one to three per cent.; an acre six inches deep would yield from ten to eighty tons.

† If too much lime is added, it may form a super-salt, less soluble an the other, and hence the liability of injuring a soil by its application. A small quantity only is required for the growth of plants.

Some plants contain sulphate of lime or gypsum, as clover, while in others, the lime is found as a *tartrate* or *malate*, that is, in combination with organic acids, which latter must have been formed before the lime could be assimilated.

Phosphate of lime is a powerful manure, and may, in small quantities, enter the organs of plants. But in this case, as in that of potash, the great point is to furnish it in any form.

5. *Alumina* is sometimes found in plants, but in very small quantities. It may enter in combination with phosphoric acid, or with crenic and apocrenic acids.

6. *Silica* or *silicic acid*. The epidermis, or outer bark of trees, the vessels in which the sap circulates, and the surface of the grains and grasses, are composed in part of this acid. As it is not soluble in water, nor in cold alkalies, the most common solvents in the soil, it has been a point of some difficulty, to determine the form in which it can be introduced.

It is supposed by some, that it is combined with crenic acid, a compound which is found in river water, and in the soil. This substance must enter the roots of plants with water, and may then be assimilated.

It is possible, however, that the silica, found in plants, is introduced by means of galvanic action, or the catalytic force of life.

There is still another mode of introducing this substance. It forms soluble salts with alkali, as potash, and when first liberated from its combinations, according to a well known law, the silica becomes soluble, and capable of entering the organs of plants.

7. The metallic oxides of iron and manganese are found in some plants, and are derived from the soil. Iron is the

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One grain of lime, in a hundred of the soil, will produce fertility, where all was barren before.

most widely diffused substance in nature, nearly all rocks containing traces of it. Iron is found in many seeds.

Manganese is nearly as widely disseminated, but is found in still less quantities, both in the soil and in the organs of plants.

8. *Phosphoric acid* has been found in all plants hitherto examined, and always in combination with alkalies and alkaline earths. The seeds of different grains form a large quantity of phosphate of magnesia. This acid is derived from the soil, and is an ingredient in all lands capable of cultivation. Phosphoric acid has also been detected in all mineral waters. Sulphuret of lead (galena) contains crystallized phosphate of lead. Phosphate of alumina often encrusts rock crystals. Phosphate of lime is found in many rocks, and even in volcanic bolders. There can be no doubt but that this acid is developed in the soil, and supplies phosphate of lime to plants, and plants furnish it to the bones and brains of animals.

9. *Sulphuric, nitric and carbonic acids,* combined with potash and other alkalies, and common salt, or chloride of sodium, are found in some plants.

Nitrate of potash is formed during the fermentation of manures. Sulphuric acid is formed from the sulphuret of iron which is found in most rocks.

Common salt, (chloride of sodium,) must come from the sea, or from animal manures, as it could not be retained in the soil, owing to its solubility. Very small quantities of oxide of copper, and some metallic fluorides are absorbed by some plants, although we cannot affirm, that they are necessary to their growth.

10. Some plants also take up small quantities of iodine and bromine in the form of iodides and bromides; but whether they are necessary to the growth, cannot be fully ascertained, although it is probable they are, since such plants are never found away from the sea, the source of these sub-

stances. Sea plants seem to be collectors of iodine and bromine, just as land plants are of alkalies, such as potash, etc.

We do not know in what form all of these inorganic constituents of plants enter the organs, nor the changes that are wrought upon them in the process of assimilation; but we may derive from the doctrine of transformations already described, the general nature of the process, and the best idea we can obtain of nutrition and assimilation.

Thus it appears, that the inorganic constituents of plants are as indispensable to their perfect development, as the carbon, oxygen, hydrogen and nitrogen. It is therefore of the first necessity, that these substances should be supplied to plants in their proper proportion. The facts developed in this section, relative to the source of the constituents of plants, illustrates the need there is of proper attention to the soil, as it is from the soils that most of the ingredients, necessary to their perfect growth are derived.

Having now considered the general conditions requisite to the life of vegetables, with the various changes which take place in the phenomena of vegetation, we will here close the subject of Biology; not because we have exhausted it, but because enough has been advanced, to give the reader a general idea of the vegetable processes, and of the utility of supplying the proper conditions, for the life and growth of those vegetable substances, which are the support of the animal kingdom. Any means, which shall increase these products, are to be sought out with the most diligent care; we have, therefore, devoted a large portion of succeeding chapters to the subject of the soils, as the most direct means of securing so desirable an end.

GEOLOGY AND CHEMISTRY OF SOILS.

CHAPTER IV.

ROCKS AND THEIR RELATIONS TO VEGETATION.

Soil is formed by the decomposition and wearing down of the rocks, which are mingled with variable quantities of animal and vegetable matters. All soils consist of compound bodies, and these compounds are generally formed, by the union of two or three simple substances. In order, therefore, to understand the nature of soil, and its relations to vegetation, it will be necessary to give a general view of the simple and compound bodies, which enter into the composition of the rocks, the manner in which they are combined, and the process by which the rocks are converted into soil.

Sect. 1. *Simple Bodies which enter into the Composition of the Rocks.*

The number of simple bodies known to chemists, is fifty-five. Of these, only fourteen enter into the composition of rocks and soils; hence, these fourteen bodies constitute nearly the whole matter of the globe. The remaining substances are found either in too small quantities to affect the general mass, or exist only in particular locations of limited extent.

The proportion in which these bodies exist in the rocks, beginning with the most abundant, is nearly in the following order; oxygen, silicon, calcium, aluminium, potassium, iron, hydrogen, sodium, magnesium, manganese, carbon, sulphur, phosphorus and nitrogen.

Some of these substances, with their combinations, have been described in previous chapters. It is intended here, to arrange them into their natural groups, and to give a general description of those which have not yet been referred to.

I. Seven of these simple bodies already described, viz. oxygen, hydrogen, carbon, nitrogen, sulphur, silicon and phosphorus, are non-metallic substances. With the exception of oxygen and nitrogen, they are *combustible*, and with the exception of carbon, do not exist in the rocks in their pure state.

II. The remaining substances are *Metals*. These are divided into three groups. 1. Potassium and sodium, which are metallic bases of the alkalies potassa and soda. 2. Aluminium, calcium and magnesium, which are the metallic bases of the alkaline earths alumina, lime and magnesia. 3. Iron and manganese, which are the bases of metallic oxides.

Potassium is a white metal, lighter than water, and so soft, that it easily yields to the pressure of the fingers. It is the most combustible of the simple substances. This is owing to its affinity for oxygen, which it will abstract from water with such rapidity, as to burn upon its surface with a beautiful purple flame. It thus decomposes the water, and forms the alkali potassa, which is the basis of potash. It is widely disseminated in the rocks, though not in very large quantities.

Sodium is also a white metal, like silver, lighter also than water, but a little heavier than potassium, to which it is similar in texture and consistency. It is less combustible than potassium, but will also rapidly decompose water to obtain its oxygen, with which it forms the pure alkali soda, the basis of all the compounds of soda, known under the names of common salt, glauber's salts, etc.

Magnesium is a pure white metal resembling silver, very malleable, and fusible at a red heat. It combines with oxygen and forms magnesia, which possesses alkaline properties, and is the basis of the common magnesia (the carbonate) and epsom salts. It exists in serpentine rocks.

Aluminium is a grey powder, slightly cohesive. It generally exists in small scales or spangles of a metallic lustre. When combined with oxygen, it forms alumina the basis of all clays, and is a constituent of most rocks, especially of the primitive and tertiary formations.

Calcium is a white metal, and combines with oxygen and forms lime, the basis of all lime rocks, shells, marble, chalk, plaster of Paris, etc.

Iron is a well known metal, existing in all the primitive rocks, in combination with oxygen and sulphur.

Manganese is a more rare metal, of a greyish-white color, existing in primitive rocks in combination with oxygen, and is called oxide of manganese, or peroxide of manganese.

Chlorine, *iodine* and *bromine* are found in sea-weeds ; *fluorine* and *lithium* exist in some plants, but in small quantities.

Sect. 2. *Compounds formed by the fourteen simple Bodies.*

I. *Primary compounds*, or *bodies composed* of two simple substances.

The combinations of these fourteen simple substances, above described, form three distinct classes of primary compounds. 1. Acids. 2. Alkalies, or alkaline earths and metallic oxides. 3. Urets.

1. *Acids.* Of this class, only five or six enter into the composition of rocks ; viz. silicic, carbonic, sulphuric, phosphoric, nitric and hydrochloric or muriatic acids. These acids have been described pp. 48, 168. The silicic is most abundant in the rocks, constituting about forty per cent. of the crust of the globe. Carbonic acid ranks next in quantity. Then follow the others, in the order above named.

The most important property of acids is their constant desire to unite with alkalies, alkaline earths and oxides; and as they possess different degrees of affinity for *bases*, they are in the soil constantly exchanging them.

2. *Alkalies, alkaline earths* and *metallic oxides*. The alkalies are potassa, soda and ammonia. The alkaline earths are lime, magnesia and alumina. The oxides are oxides of iron and of manganese. These with the exception of the two last, do not exist in the rocks in their pure state, but their agency in the soil is of the highest practical interest to the farmer.

3. *Urets*. The urets are bi-elementary compounds, neither acid nor alkaline. They are formed by the union of the non-metallic combustibles with each other and with metals. The principal are sulphuret of iron, (iron pyrites), phosphuret of iron, carburet ofiron, phosphuret of lime, phosphuret of silicon, etc.

Their distinguishing property is, a readiness to change into salts through the influence of atmospherical or other agents.

II. *Secondary compounds* or *salts*. These are compounds formed by the union of the primary compounds. The acids combine with the alkalies, alkaline earths and oxides, which are called, in reference to the acids, bases, and form ternary or quaternary compounds.

Salts may be conveniently classed under their respective acids.

1. *Silicates*. The silicates are those compounds or salts, in which silicic acid combines with the bases above named. Those entering into the composition of the rocks, are the following: silicates of potassa, soda, lime, magnesia, alumina, oxide of iron and of manganese. Almost the entire mass of rocks is composed of these *silicates*, and from seventy to eighty per cent. of soils. These salts when neutral, are not soluble in water, and therefore are not capable of being dissolved in that fluid, except in very minute quantities; hence,

they remain unaffected, unless substances are presented capable of decomposing them, and of forming soluble compounds.

2. *Carbonates* are a class of compounds formed by the union of carbonic acid with the bases above mentioned. All, excepting the carbonate of lime, or marble, are found in small quantities in the rocks.

Carbonate of lime is very abundant, forming nearly $\frac{1}{7}$ part of the crust of the globe.

Carbonate of potassa is the common potash, pearlash, etc. and is usually obtained from ashes.

Carbonate of soda is the well known substance used for soda powders.

Carbonate of magnesia is a white powder used in medicine, under the name of "calcined magnesia."

Carbonate of iron is more widely diffused among the rocks, but the quantity is small.

Carbonate of ammonia is a powerful stimulant to animal and vegetable organs, and is found in the fermentation of animal manures, and exists, according to Liebig, in the atmosphere. It is, as we have seen, one of the substances from which plants derive their nitrogen. All the carbonates are easily decomposed, and have an important influence on vegetation, especially by means of their action upon the silicates from which alkali is obtained for the use of the vegetable.

3. *Sulphates.* The sulphates are formed by the union of sulphuric acid with potassa, alumina, soda, magnesia, ammonia, lime, oxide of iron and of manganese. Most of the sulphates are well known substances. The sulphate of potassa and alumina is known by the common name, *alum.* Sulphate of soda is glauber's salts; of magnesia, epsom salts; of lime, plaster of Paris; of oxide of iron, copperas, etc. The most abundant sulphate is that of lime or plaster, which forms extensive mountain ranges and is widely disseminated among the rocks.

4. *Nitrates.* The nitrates are compounds of nitric acid

with the bases above named. The nitrate of potassa is the nitre or salt-petre of commerce. The other nitrates are rarely found in the rocks. Nitrate of soda is next to nitre in importance.

5. *Phosphates.* In these compounds, the acid is the phosphoric, and the most abundant salts are the phosphates of lime, found in most rocks; phosphates of iron, soda, potassa, etc.

6. *Muriates.* The muriatic acid forms but few compounds, which exists in any considerable quantities in the rocks. Common salt, when dissolved in water, has been regarded as a muriate of soda. It is found in sea water, and widely diffused in certain geological formations, (the new red sandstone,) but most writers regard it as a chloride of sodium, a compound of chlorine and sodium.

The compound bodies, which have been enumerated, are, with the exception of silicic acid and carbonate, sulphate and phosphate of lime, rarely found in the rocks in a pure or separate state. They are variously combined, and form the *natural substances*, called the *simple minerals;* and the simple minerals, united mechanically, and not chemically, form the rocks.

In order to understand the character of the rocks and the soil, it will be necessary to describe these compounds, as they actually exist in nature.

Sect. 3. *Simple Minerals which enter into the composition of the Rocks.*

Of the three or four hundred species of simple minerals, only seven or eight form the great mass of the rocky strata of the globe. These are quartz, mica, feldspar, hornblende, talc, serpentine, calcareous spar, or limestone and pyrites.

1. *Quartz* is nearly pure silicic acid. It exists under a a great variety of forms, and presents different appearances. The purest variety is rock crystal, which is limpid and

transparent. The impure varieties contain variable quantities of iron, alumina, manganese and nickel. These varieties are found under the names of jasper, flint, chalcedony, rose-quartz, horn-stone, chrysoprase, feruginous quartz, cornelian, agate, amethyst, etc. The prevailing color is that of water, or white. There are various shades of red, yellow, green, blue and brown. It is so hard as to scratch glass, but is not scratched in turn. Its lustre resembles glass, and may be known by not being acted upon by any acid, excepting the hydrofluoric.

2. *Feldspar* differs from quartz in having a paler white color, and lamella or granula texture. It scratches glass, and is scratched by glass in turn. It is a silicate of alumina, and is composed of silica, 64 parts in 100, alumina 20, potash 10 to 14, and traces of lime, oxide of iron and water.

3. *Mica.* This mineral, known under the name of isinglass, exists in thin, shining scales, and in broad tables or plates. It is of various colors. It is transparent, and the laminæ are thin, very flexible, elastic and very tough. These characters sufficiently distinguish it in the rocks. It is a *silicate*, and varies in composition. A specimen analyzed by Rose, gave

Silica	47.50	Oxide of manganese	0.96
Alumina	37.2	Fluoric acid	0.56
Potash	9.60	Water	1.39
Oxide of iron	3.20		

A specimen, analyzed by Turner, had 5.49 of lithia, but no oxide of iron. Its composition may be stated generally

Silica	48	Oxide of iron	1 to 2
Alumina	34	Oxide of manganese	1 to 2
Potash	8 to 9		

It appears, therefore, to be a compound of the silicate of alumina, potassa, oxide of iron and of manganese.

4. *Talc* resembles mica in its thin, shining scales, but may be distinguished from it by its want of elasticity. It is

softer, yielding easily to the nail, and has a soapy feel. It includes the varieties, chlorite (which is green), nacrite, green earth, steatite or soapstone, and vermiculite.

It is composed of silica 62, magnesia 27, oxide of iron 3.5, alumina 1.5, water 6. Nacrite and green earth have from 4 to 17 per cent. of potash, and a trace of lime. It appears to be a silicate of magnesia, and of the other bases which are above mentioned.

Hornblende is a black or brown mineral, exceedingly tough, and of an earthy appearance when not crystallized.

It is composed, according to the analysis of Bornsdorf, of

Silica	43.83	Protoxide of iron	18.75
Magnesia	13.61	Protoxide of manganese	1.15
Lime	10.16	Hydrofluoric acid	0.41
Alumina	7.47	Water	0.50

Hence it is a silicate of magnesia, lime, oxide of iron, etc.

Serpentine. Serpentine is a hard compact mineral, of a resinous or greasy lustre, and of a dark-green or blackish-green color. According to the analysis of Shepherd, it is composed of

Silica	40.08	Water	15.67
Magnesia	41.40	Protoxide of iron	2.70

A species from Lynnfield, Mass. analyzed by Dr. C. T. Jackson, gave silica 37, magnesia 42, oxide of iron 2, water 15. Hence, serpentine is almost wholly a silicate of magnesia.

Calcareous spar, or carbonate of lime, is well known by the names of marble, chalk, limestone, etc. It assumes a great variety of forms, and may be known by the brisk effervescence produced by dropping on to it a few drops of sulphuric acid. It is composed, according to Phillips, of carbonic acid 44, lime 55.5. Limestone is found, in great abundance, but it is not always pure. It often contains magnesia, the dolomite species; iron; the feruginous limestone; alumina; and silica. The limestones of Rhode Island, according to the analysis of C. T. Jackson, contain from 50 to 97.6 per cent.

of carbonate of lime; from 1 to 40 per cent. of insoluble matter, probably silicate of alumina; in some cases, 4 per cent. of oxide of iron, from 0. to 40 per cent. of magnesia. The limestones of Massachusetts, according to Prof. Hitchcock's analysis, contain from 44.8 to 99.6 per cent. of carbonate of lime; from 0 to 40 of carbonate of magnesia in some species; from 0 to 8 per cent. of carbonate of iron; and from 0.4 to 61.6 of silicate of alumina. The sulphate of lime or plaster, with the phosphate, may also be included in this group, as in some cases entering into the composition of the rocks.

Pyrites, or iron pyrites, is a bisulphuret of iron, and exists extensively in primitive rocks, but in much less quantities than the preceding minerals. It resembles gold, and is often taken for that substance; hence it has been called *fool's gold.*

It will be seen that silex or silicic acid is the most abundant ingredient in those simple minerals above enumerated, and alumina the next. They are mostly silicates and are divided by Dana into three classes.

1. Silicate of alumina and potash form feldspar and mica.
2. Silicate of alumina and lime, with magnesia, form hornblende.
3. Silicate of alumina and magnesia form serpentine and talc, and silicic acid forms quartz.

Sect. 4. *Composition of the Rocks.*

Rocks are composed of the simple minerals. In some cases, the minerals may be seen in separate portions, united mechanically, as in granite. In other cases they are so intermingled as to conceal their distinct characters, as in greenstone. Rocks are divided by geologists, according to their supposed origin, into two separate classes. 1. *Igneous* rocks, or those which appear to have been fused by fire. 2. *Aqueous* rock, or such as appear to have been deposited from water, or which have resulted from the decay and wearing down of the first class. The igneous rocks are highly crystalline in their structure; such as granite, sienite, gneiss, greenstone, porphyry, basalt, and ancient and modern lava. They constitute the largest portion of the crust of the globe. They are destitute of animal or vegetable remains, and hence are called *non-fossiliferous* rocks. The aqueous rocks include the various deposits of clay, sand, gravel, conglomerates, sandstones, slates, etc. They are composed, essentially, of the ingredients of the igneous rocks. They contain, with the exception of a few rocks in the lower part of the series, the remains of animals and plants, and are hence called *fossiliferous* rocks.

Rocks are subdivided into several groups. The unstratified or non-fossiliferous rocks, may be divided chemically into two. The highly crystalline varieties, usually called primary, such as granite, gneiss, mica slate and porphyry, form one class, and the *trappean* rocks, such as greenstone, basalt and trap, form the other class. The difference in their chemical constitution is this; that the first class contain about 20 per cent. more of silex, and from 3 to 7 per cent. less of lime, magnesia and iron than the second class.

The fossiliferous rocks are very various in composition, although they correspond more nearly to the trappean variety "in containing less silica and more lime, magnesia and alumina."

The following are some of the most abundant rocks, composed of the simple minerals.

1. *Granite* is composed by the mechanical union of quartz, feldspar and mica. The quartz is in irregular masses, the feldspar often crystallized, and the mica in thin shining scales. Hornblende sometimes displaces mica and forms what has been called *sienite.*

2. *Gneiss* is similar in composition to granite, but appears to be formed by the destruction and deposition of the granite by water.

3. *Mica slate* is formed by quartz and mica, the latter pre-

dominating so as to give the rock a slaty and shining appearance.

4. *The argillaceous slate* and clay slate are made up principally of quartz and alumina, or argillite, which seems to be decomposed feldspar, containing from 7 to 10 per cent. of potash.

5. *Talcose slates* consist of talc, alumina and quartz.

6. *Hornblende rocks* and hornblende slate are composed mostly of hornblende.

7. *Graywacke* is formed of quartz, clay slate and lime.

8. *The trappean* rocks have a similar constitution.

9. *Limestones* generally contain clay, feldspar, porphyry and clay slate, although there are extensive beds of the pure carbonate of lime.

10. *The various sandstones* and slates are composed mostly of silex and alumina, and hence are formed of the minerals quartz and feldspar.

Sect. 5. *Origin of Soils.*

Having attended to the manner in which the simple bodies are united to form the rocks, the way is now prepared to describe the process by which the rocks are converted into soils.

The researches of modern geologists have established the fact, that all soils were originally formed by the disintegration, decomposition and wearing away of rocks. The rock has been gradually pulverized, and brought into the condition of soil. This effect has been produced by the mechanical and chemical agency of *air, water, living* and *decaying vegetables.* This process is constantly going forward.

1. *The oxygen of the atmosphere* combines chemically with the metals and decomposable minerals, and, by forming new compounds, causes them to crumble down. Water also imparts its oxygen, and produces a similar effect. The surface

of rocks, in this way becomes pulverized to a greater or less depth.*

The principal mineral substances with which the oxygen of the air and of water unite, are *iron*, *manganese* and *pyrites*.

When a rock contains iron or manganese, in a low state of oxidation, these oxides attract more oxygen from the air and water,† increase in bulk and split or cleave into their layers; thus affording an opportunity for the mechanical agency of water, either by friction or by freezing.

2. *Pyrites*, or the bi-sulphuret of iron, exerts the most powerful agency in the decomposition of rocks, and perhaps the most extensive; as this mineral is widely disseminated through nearly all classes of rocks. It is composed of sulphur and iron. The *sulphur* attracts oxygen from the air and from water, and forms the well known substance sulphuric acid (oil of vitriol). The iron also combines with oxygen from the same source, and forms an oxide of iron. The acid and the oxide now unite and produce a new compound, the sulphate of iron or *copperas*, a substance capable of being dissolved in water. Thus the rock, through which the pyrites is disseminated, is crumbled, thrown or changed in its properties. But the action does not stop here. The sulphate of iron, being dissolved in water, which is constantly penetrating the mass, is brought into contact with feldspar, and both are decomposed; the sulphuric acid in the copperas abandons the iron, and unites with the potash and lime in the feldspar, forming sulphate of potash and of lime, while the oxide of iron is deposited in the form of *iron rust*.

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* This process is called *disintegration*, and some examples are found in Massachusetts, where the gneiss rocks have been penetrated fifteen feet. The rock is said to rot. Almost every variety of rock is constantly undergoing this change.

† This action of the oxygen of the air and of water to produce disintegration, explains the effect of allowing lands to remain fallow, by which their fertility in a measure is restored

When the pyrites exists in *slate* rocks, containing much alumina, magnesia and lime, the sulphuric acid combines with these bases, by which nearly the whole rock is gradually converted into soil. Were this the only agent acting upon the rocks, the character of the soil would be accurately known, by examining the rock which underlays it; but this is rarely the case.

3. The mechanical agency of water, aided by cold and heat, and by its currents and waves, not only aids in breaking down the solid masses, but transports the pulverized materials in the form of detritus, and deposits them in lower lands. Thus the substances of different rocks are mingled together. Freezing water exerts an immense power in this respect. The water penetrates every seam and crevice of the rocks, and, by its expansive power in the act of freezing, forces the parts asunder, and creates new fissures, which are each year increased in number and width. Nor does this influence cease after the rocks are fully converted into soils; each year the expansive force of water tends to pulverize, and render the earth light and porous.

The *friction* of running water wears off the rocks, and removes that which has become broken down by chemical action. The particles being suspended are carried down by the force of the stream, and deposited along the banks and at the mouths of rivers.

That the agency of water, at some ancient period, has exerted a very great influence upon the rocks and soils appears from the fact, that over the whole northern hemisphere, the rocks and soils have nearly all been removed in a southerly direction, and the materials of different formations variously mingled together. This has been shown to have resulted from the action of glaciers, by which the whole surface has become scratched, and the sand, gravel and boulders rolled up into hills, with ponds and vallies between.

4. *Decaying plants* tend to convert the rocks into soils.

The vegetable acids are capable of combining with the lime, soda, ammonia, potash, magnesia, oxide of iron and manganese. These bases are thus withdrawn from the rocks, and the latter crumble to pieces, and salts are formed, which are useful in the nourishment of future generations of plants. During decay, large quantities of *carbonic acid* are formed. This acid is not only direct food for plants, but is capable of combining with the potash in the feldspar of granitic rocks, and of facilitating their decomposition. This acid is the most powerful agent in its action upon the alkalies, even decomposing the *silicates* and forming soluble salts.

5. *Growing plants* exert the most powerful agency in decomposing the rocks. Not only do the lichens, mosses and other plants insert their roots into the crevices of the rocks, and by keeping them moist, favor the chemical action of air and water, but the living plant forms with the rock or soil a *galvanic battery*, of immense power; by this means the plant is enabled to obtain from the soil those ingredients which its wants may require. This is proved by the fact, that plants, growing in glass vessels, will decompose the glass to obtain the potash, of which the glass is in part composed. It is highly probable, that a greater amount of decomposition is produced in this way than by all other causes together. Similar to this influence, if not identical with it, is what has been called "*catalysis of life*." The living plant acts by its presence to decompose the rocks, and to effect rapid changes, which not only convert them into the state of soil, but form the elements into different substances.

The above process will serve to illustrate the chemical and mechanical agencies which are constantly at work to crumble down the solid rocks, and bring them into a state fit for the support of the vegetable kingdom. These agents are constantly active. The great effect of stirring the soil, is to facilitate the decomposition of the rocks, and of the vegetable bodies which are always present in the soil. But for this agency, the soils in a few years would become exhausted of all their alkalies, the vegetable matter would not decay, and hence no food in the soil would be provided for the plant. Absolute barrenness must therefore succeed. For without alkalies or alkaline earths and geine, no plants can grow.

Depth of soil. The influence of the agents above described, has not extended to an average depth of more than 15 feet; although in some places, the soil is actually more than a hundred feet in depth. This is but a small portion of the whole mass of the earth, whose mean diameter is 7,911 miles; hence "the soil would be less in proportion to the whole earth, than the slightest tarnish of rust on an iron globe 100 feet in diameter compared with *its* mass." But a small part of this constitutes what is properly denominated the *soil.* That part only of the surface, varying from 3 to 20 inches in depth, which has become mingled with vegetable and animal matters, constitutes the true soil, and it is mostly this part, which concerns the farmer, and which is presented for our investigation, classification, description and improvement.

CHAPTER V.

SOILS AND THEIR RELATIONS TO VEGETATION. THEIR ANALYSIS, COMPOSITION, MUTUAL ACTION OF THEIR ELEMENTS, GEOLOGICAL AND CHEMICAL CLASSIFICATION AND DESCRIPTION.

The relation, which the soil sustains to vegetation, has been pointed out in a general way in the first chapter, p. 81, where it was shown to be one of the essential conditions to the action of the vital power in those vegetables which were cultivated for the use of man; furnishing support for the roots, a medium for the circulation of water, and for those chemical and electrical changes which must take place, before the nutriment could be prepared and introduced into the vegetable organs; and yielding, by its salts and mineral ingredients, both food and stimulus to growing plants. It was remarked, however, that all soils did not perform these offices with the same degree of fidelity, but a few were fitted, without artificial appliances, to facilitate the vigorous action of the vital principle, and the perfect development of all the vegetable organs.

We propose now to consider the soil as a specific subject of investigation, to give the modes of its analysis, to point out its chemical and geological character, and the relation of each variety to the cultivated crops. By this method, the intelligent agriculturist may learn the nature of his soils, the general mode of improvement, and howto adapt his crops to such as are fitted by nature or art to yield the most bountiful crops.

Sect. 1. *Analysis of soils.*

The importance of a correct knowledge of the constituents of any soil, appears from the fact, that without it, all experiments must be conducted in the dark.

A want of such knowledge, has given rise to the various discrepant views of farmers, relative to the application of certain salts of lime. Experiments are tried by one farmer, and he is successful; another applies the same substance and fails; hence we have the most contradictory accounts of nearly every mode of improvement, and the consequence is that, though there are constant improvements, in individual cases, no generalization can be made applicable to every kind of soil. An analysis of a soil will indicate at once the mode of treatment. There can be no doubt here, as the most fertile soils of our own and of other countries, have already been analyzed, and their composition accurately ascertained.

Any farmer, then, who can analyze his soil himself, or procure it done by some scientific chemist, may compare its composition with that of fertile soils, and the exact mode of improvement will be seen at a single glance. This excludes all empyricism, all hap-hazard experiment, all unnecessary expense,* and, for a trifling sum, will ensure complete success. The grand desideratum, in this, as well as in every other art, is the *the union of theory and practice.* Agriculture should not be pursued as a mere art, a routine of mechanical drudgery, but the scientific principles upon which the success of the art must ultimately depend, should be thoroughly understood by every farmer.

Why should the agricultural community be the only class who are not educated in the science of their profession? Why should they suffer their art, the first and the most important of all others, to rank lowest in the scale?†

It is not expected, that every farmer will have a laboratory, furnished with all the materials necessary to a complete and accurate analysis of his soils. This must be left to a few practical chemists, but the rising generation of farmers, may very easily obtain such knowledge, as will enable them

* For the trifling sum of ten, or at most, twenty dollars, almost any farmer can ascertain the composition of any of his fields, and have the mode of improvement pointed out. This, without doubt, would be more than returned to him in a single season, and would be increased in tenfold proportion in succeeding years. Were half the time and money, which have been wasted in useless experiments, without any *scientific principles to guide*, expended for the purpose of analysis, our farmers would, long ere this, have had the satisfaction of seeing their farms gradually, but surely, arriving to a state of fertility, of which they had never dreamed; and instead of going West to seek more fertile lands, would actually be able to compete with the Western farmer in any market under heaven.

† If, with the rapidity of improvement among every other class, our farmers do not take care of their interests, by improving their minds and studying their professions, they must be looked down upon, and justly too, as the lowest in the scale of being; as incapable of a high state of civilization.

to make examinations which will indicate the course of improvement. They may learn all that is absolutely essential to the highest success in their profession, and that which will not only prove the means of a competency for themselves and families, but which will also furnish the highest means of intellectual and moral improvement, and the sources of increasing influence and happiness. This section will therefore be devoted to the description of several modes of analysis, for the purpose of learning the composition of various soils. It may serve also to convince the farmer, that whether he is able to adopt any of the modes himself or not, the subject is one which appeals, not only to his intelligence, but to his interest, and to the dignity of his profession.

I. *Mechanical analysis and tests.*

The mechanical analysis of soils may be performed by any man "capable of driving a team or holding a plough."

Apparatus. The apparatus required for a mechanical separation of the particles of a soil, are 1st, two sieves,* one of copper wire, with meshes $\frac{1}{10}$ of an inch square, and the other of fine gauze, with meshes $\frac{1}{50}$ of an inch in diameter. 2d, A glass jar, or common glass bottle. 3d, A balance, capable of turning with a grain weight, and a set of weights, from 1 to 1000 grains. The whole need not cost more than fifteen or twenty dollars.

Process. Having selected 1000 grains of soil to be analyzed or tested, heat it, for twenty minutes, at a temperature just below that at which straw turns brown, so as to evaporate the water. Weigh the soil again, and the loss will give nearly the quantity of water which the soil is capable of absorbing. It is important to note this, as some knowledge may be obtained from it, useful to the farmer. For example, it is found that those soils which absorb the

* Sieves brought from Canton, and sold by apothecaries, answer the purpose very well.

most moisture, are richest in vegetable mould or geine, and by comparing this power in different soils, we may arrive at valuable knowledge as to their comparative fertility.

2. The next step in the process is to bruise the whole, so that no lumps can be found in it, and then sift it through the coarse sieve. What remains too coarse to pass through, will consist of pebbles and fibres of wood. This may now be weighed and tested. The pebbles may be broken with a hammer, and their nature ascertained by inspection, or they may be tested by acids.

To test them by acids, a few grains may be bruised, if need be, put into a clean glass, flask or tumbler, and covered with water. Half as much hydrochloric (muriatic) acid as water may be added, and if they are calcareous, small bubbles of gas will pass up through the water. If they are wholly carbonate of lime, the acid will completely dissolve them. But this is not to be expected in any of our soils. It is very rare, that the least trace of carbonate of lime will be found in this portion. If the coarse parts do not effervesce with acids, they are composed entirely of silica and alumina, or of a mixture of both, which is generally the case. These two bodies may easily be distinguished from each other. The silica is rough like sand, scratches glass, etc., and the alumina is soft and unctuous to the touch. If any animal or vegetable substance is mixed with the coarse particles, by burning a portion of them, the odor of peat or sponge will be given off, then by carefully weighing a quantity before and after burning, the amount of organic matter may be ascertained.

3. Sift the soil again through the fine sieve, and weigh the quantity which remains in the sieve. It will consist of sand and fine vegetable fibres. This may be tested in the same way with the coarser particles, and the amount ascertained.

Take now the fine powder, which passes the gauze sieve, and agitate it for a while in a given measure of water, pour off the suspended matter upon a filter.* This will consist mostly of vegetable substances, clay and fine sand. By examining the residue in the glass jar, the larger particles of the mineral ingredients can easily be detected. Put the contents of this jar on the other filter, and after the water has passed out, the filters with their contents may be weighed, and the relative proportions determined. If the filter contain free acid, little lime water will cause a white precipitate, which is either a sulphuric or carbonic acid; if the latter, the precipitate will effervesce with sulphuric acid, and will be converted into gypsum, or sulphate of lime. To ascertain whether there is any sulphate of iron or copperas, pour into the liquor a few drops of the infusion of gall-nuts, and it will give a dark or brown color.

To test for oxide of iron, wash the filter, containing the clay and fine particles, with diluted muriatic acid, and apply the infusion of galls; and if it becomes black, it contains iron.

The above process can be easily performed, and some valuable knowledge obtained. It may be known, for example, whether the soil is mostly silica or alumina, or whether it contains free acid, like the sulphuric, or whether the acid is combined with oxide of iron, a substance very injurious to vegetation; but which is, by the application of lime to decompose the copperas, easily converted into gypsum (sulphate of lime), a valuable manure. The above method, however, cannot be depended upon where accuracy is required, and we will now proceed to describe a method of analysis which is very simple, and which some farmers may be able to adopt. It is substantially the method of Dr. Samuel L. Dana, of Lowell, Mass.

* The filters may be made of fine linen cloth, of equal weights, placed in a common glass tunnel, and lined with unsized paper.

II. *Chemical Analysis of Soils.*

Object of this analysis. The object of this analysis is to ascertain the water of absorption; the quantity of soluble geine, which will indicate the quantity of food already prepared for vegetables; the amount of insoluble geine, which will show what food is unprepared as yet for the plant; salts of lime and mineral constituents. The latter may all be reduced, according to Dr. Dana, to granitic sand; that is, the earthy ingredients of all our soils, are composed of the fine detritus of granite, gneiss, mica slate and argillite. Now, as these earthy ingredients may vary considerably in their proportions, without affecting the fertility of the soil, they are always prepared for their office, and are only changed for the better by cultivation. But this is not the case with salts and geine. Any considerable variation here, will cause barrenness. Salts and geine are the substances which are removed by the plant, and must therefore be constantly supplied to the soil, or the land will soon become exhausted. The great object then of analysis, is to determine the quantity of soluble and insoluble geine and salts. This is all the farmer needs to know, which may not be learned by inspection of the soil, or by the descriptions which have already been given. The relations of the soil to heat and moisture, depend chiefly upon *geine.* The larger the quantity, the greater the absorbent power of the soil, both as respects water and caloric.

Mode of Analysis. 1. To determine the absorbent power of soils, sift the soil through a fine sieve, and take a quantity of the finer portions, and heat it to 300° F. Then weigh out 100 grains on a piece of glazed letter-paper, expose it to the atmosphere from 24 to 36 hours, weigh again, and the quantity gained will be the absorbent power of the soil. Note this in a *Journal* kept for the purpose.

2. To determine the quantity of soluble geine. Bake the

soil, which has passed through the finer sieve, just up to the point at which paper becomes brown, but not sufficiently to scorch it. Weigh out 100 grains of the baked soil, as above, and boil it for half an hour, in a solution of 50 grains of saleratus, or carbonate of potassa,* dissolved in 4 oz. of water. When it has settled, the clear liquor may be poured off, and the residue washed in 4 oz. of boiling water.

The whole is now to be thrown upon a filter, which should be previously dried at the same temperature with the baked soil, and carefully weighed. Wash the soil upon the filter until the water passes through colorless. If carbonate of ammonia is used, instead of washing the soil, it should be digested with the same quantity of the solution, at least twice, and then washed until there is no alkaline reaction in the water as it passes the filter. Mix all these liquors together, and they will form a brown-colored solution containing all the *soluble geine.* The sulphates have been converted into carbonates, which, with the phosphates, are on the filter with the soil. Dry the filter, raising the heat gradually to above that of boiling water, and then weigh the contents. The loss is the quantity of *soluble geine.* Note this also, and mark the filter 2.

3. To test the accuracy of the analysis thus far, precipitate the geine from the alkaline solution, with excess of lime-water. The geine will combine with the lime, forming the geate of lime, and when a sufficient quantity of lime-water has been added, the liquor will be colorless. Throw the whole upon a weighed filter, and wash with a little acetic, or very dilute hydrochloric acid, and this will combine with the lime, and pass through the filter, leaving the geine quite pure. Dry and weigh as before. If this quantity corresponds with

* Dr. C. T. Jackson objects to carbonate of potassa, because it is impossible to wash out the last traces of it from the vegetable fibre, and because the subcarbonate of potassa takes up a portion of the alumina.

that by the first process, there can be no doubt of the accuracy of the result.

4. Place the filter (2) with its contents upon a funnel, and wash with 2 drams of muriatic acid, diluted with 3 times its bulk of cold water. Wash the filter, until tasteless water passes through. The acid will dissolve the carbonate and phosphate of lime; the iron which may arise forming salts of iron, present in the soil; and the oxide of iron. The two latter exist in very small quantities in most soils, and as the sulphuret and sulphate of iron, in the process of cultivation, are converted into sulphate of lime, the whole may be regarded as a solution of the salts of lime. Evaporate the solution to dryness, weigh it, and it will give the quantity of these salts.

5. To separate these salts, dissolve them in boiling water. A part will be insoluble. Throw the whole upon a filter, and weigh as above. The insoluble portions will be phosphate of lime, and the loss will be the sulphate of lime. Note the quantity of each.

6. To determine the quantity of *insoluble geine.* The residual soil may now be burned in a silver or platina crucible, and the loss of weight will give the quantity of insoluble geine contained in the soil. The only source of error here, will be due to the loss of water in any hydrate which may exist in the mass burned. But it is found by experiment, that in our soils the quantity is rarely sufficient to affect materially the result.

7. The weight of the mass after calcination is "granitic sand," composed mostly of clay, mica and quartz, all of which may be tested by methods already given.

It will be seen, that by this process the quantity of lime is not detected, but this is of very rare occurrence in the soils of this country. From an analysis of one hundred and twenty five specimens of soils, taken from as many towns in Massachusetts, only seven contained any quantity of carbonate of lime, and from the analysis of a great variety of soils in New England and the Western States, only a few have any notable portions of this substance, although reposing upon *limestone rocks.* The advantage, therefore, of ascertaining the quantity of this substance, may be derived from simply testing the soil with acids; a method already described. If now the results of this analysis are summed up, they will be arranged in the following order:

1. Water of absorption	4.4	4. Sulphate of lime	1.6
2. Soluble geine	5.1	5. Insoluble geine	7.5
3. Phosphate of lime	0.6	6. Granitic sand	85.2

The numbers are supplied from an analysis of 100 grains of a fertile soil in Andover, Mass.

The method of analysis employed by Dr. C. T. Jackson, differs in some particulars from that of Dr. Dana. The method employed in the analysis of the soils of Rhode Island is here inserted.

1. Having weighed out a certain quantity, say 100 grains of the fine soil, that has passed the finest sieve, it being weighed upon a square piece of glazed letter-paper, the first step is to dry it thoroughly at a temperature above boiling water, but not sufficient to scorch the paper. The soil being again weighed, its loss of weight is water, and the amount is noted in the laboratory journal, A.

2. To ascertain the quantity of organic matter, whether of vegetable or animal origin, we place the dried soil in a platina crucible, cover it closely, and heat it gradually to redness, over an alcohol lamp. By the odor disengaged during the process, we know whether the organic matter is of a vegetable or animal nature, the former having the smell of burning peat, and the latter that of burnt feathers. It is, however, difficult to distinguish the mixed odors, without much practice. Having charred the organic matter, it may now be safely burned out, by placing the open platina crucible with its contents in a clay muffle, open at one end, and exposed to a full red heat. The air circulates in this muffle, and soon burns away all the organic matter, which may be ascertained by repeatedly stirring the soil with a platina rod during its combustion, and noting whether any more particles are burning. After the operation is com-

plete, weigh again, and the loss of weight is the amount of organic matter in the soil. Note it in the laboratory journal, B.

3. To determine the amount and nature of matters soluble in muriatic acid, which will take up all the mineral substances that can be acted upon by vegetation, such as all salts of lime, iron, alumina, manganese, magnesia, potash, etc., place the burned soil B in a clean green glass flask, with a thin bottom, pour over it a small quantity of distilled water, sufficient to cover it, then drop in some muriatic acid, and note whether there is any effervescence. If so, there is a carbonate, probably of lime, in the soil. Add more acid, say about one ounce. diluted with an equal bulk of water. Boil the whole, for half an hour, or until the residuary matter is nearly white. Every thing soluble in the acid is then taken up. Dilute with distilled water and throw the whole upon a double filter. After the liquid has passed through the paper wash the insoluble matter on the filter by means of a stream of boiling hot water, and continue the operation until the water comes through tasteless. Dry the filters with their contents, separate them and burn them separately, weighing one against the other. The difference is the weight of the insoluble silicates, and is generally nearly pure silex. Note its weight, C.

4. In order to ascertain the nature and proportions of the matters that have been dissolved by the muriatic acid, you may proceed as follows:

Take the filtered solution, which must be in a green glass flask; add to it a few drops of nitric acid, to per-oxidize the iron, and boil it. Then, while still warm, add liquid ammonia, until all the per-oxide of iron and alumina are precipitated. Simmer the whole a few minutes so as to condense the bulky precipitate. Filter on double paper, wash the precipitate twelve hours with hot water, or until the liquid passes tasteless; then separate the precipitate while moist from the filter by means of a silver knife, scraping up every portion that can be removed from the filter. Place this in a large silver crucible and pour over it a solution of pure potash, in distilled water. Boil until the alumina is entirely taken up, and the oxide of iron left has a deep brown color. You may know that a sufficiency of potash has been added by letting fall into the solution a drop of muriatic acid, when flocculi of alumina will precipitate, but will immediately redissolve if there is potash enough. Dilute with distilled water, filtrate through double filters, wash the precipitate, dry the filters and their contents, separate them, and burn and weigh them against each other. The difference of their weight is that of the per-oxide of iron. Mark its weight against D.

5. To separate the alumina, you must now take its alkaline solution and acidulate it with muriatic acid; then add a solution of carbonate of ammonia in pure water. All the alumina will be thrown down in the state of a white, gelatinous, and flocky precipitate. Collect it on a double filter, wash it for 24 hours with boiling distilled water, dry it, separate and burn the filters. Weigh one against the other, and the difference of their weight will be the weight of the alumina. Mark this against E.

Now you may go back to the ammoniacal solution, from which the iron and alumina have been separated, but in practice the following processes are carried on while we are waiting for the filtrations and washings of the alumina and oxide of iron.

This ammoniacal solution may contain the lime, magnesia, and a small quantity of manganese. Add to it a solution of oxalate of ammonia which will precipitate all the lime in the state of an oxalate. Let this precipitate subside, and then collect it on double filters, washing it with warm water. Dry the filters with their contents, separate them and burn one against the other at a red heat in a platina capsule; let fall a few drops of a solution of carbonate of ammonia upon the lime, heat it again to dull redness. Weigh the result against its counterpoised burnt filter, and you will have the quantity of lime in the state of a carbonate, and may reduce it by calculation to any other salt of lime that you have found to exist in the soil. Mark the weight of this against F.

6. To separate the magnesia, add to the solution from which the lime has been separated, a solution of phosphate of soda, (it being still ammoniacal,) when the magnesia will be thrown down in the state of an ammoniaco-magnesian phosphate. Collect it on a filter, wash it but little, then dry the filters and contents, separate them, burn one against the other in a platina capsule. The difference of weight will be the weight of the bi-phosphate of magnesia, 40 per cent. of which may be regarded as equivalent to the magnesia contained. G.

7. You may now run a current of sulphureted hydrogen gas through the remaining solution, or add bi-hydro sulphate of ammonia, when all the manganese will be thrown down in the state of a sulphuret. Collect and reduce it to black oxide. H.

The analysis is complete so far as it can be done on this specimen, and you may sum up your results, and see how nearly they will balance, and if there is a loss, you must make another examination for salts of potash and soda, in the manner I shall give presently. Let us first sum up the above operations.

A Water of absorption.
B Organic matter.
C Insoluble silicates.
D Per-oxide of iron.
E Alumina.
F Lime.
G Magnesia.
H Manganese.

In order to ascertain the existence of alkaline salts, burn off the vegetable matter from another 100 grains of the dry soil. Then pour over it a little nitric acid, and digest it at a boiling heat. Dilute and filter the solution, evaporate it to entire dryness, fuse the saline matter obtained, and drop into it a few fragments of prepared pure charcoal. If nitrates are present, deflagration will take place, and the alkaline bases will be converted into carbonates. Dissolve the residue and test a drop of the solution by means of a solution of chloride of platina and soda. If potash is present, a yellow powder will precipitate, but none will fall if soda alone is present.

Sect. 2. *Composition of Soils as determined by Analysis.*

The composition of soils might generally be deduced from the composition of the rocks out of which they are formed, provided no chemical nor mechanical changes were wrought upon them in the process of disintegration. But as the proportion of the ingredients are changed in this process, as some of the alkalies are abstracted by growing plants, or removed by successive crops, and as organic matters are added, we must resort to an examination by analysis, in order to ascertain the exact composition of any soil which is presented for our inspection. By this examination, soils are found to be composed of two parts: 1. the *mineral* ingredients, or *inorganic* portions, which include the alkalies, metallic oxides, salts and earths ; 2. the vegetable and animal matters, or *organic constituents*.

I. *Mineral constituents of soils.* The mineral substances which enter into the composition of all soils, are few in number, and most of them easily detected. They may be divided into 3 classes: 1. earths; 2. alkalies and metallic oxides; 3. salts and urets.

As the rocks are mostly made up of silica, alumina, lime and magnesia, the great mass of the soil is composed of these substances, which are commonly called *earths.* The alkalies, potassa, soda and ammonia, the metallic oxides of iron and manganese, exist in all fertile soils in small quantities. The phosphates of lime and magnesia, nitrate of potash, sulphates of lime and ammonia, chloride of sodium, carbonates and other salts, are almost always present in soils; and, in some cases, sulphurets, phosphurets and carburets of iron exist in very small quantities.

In one view of the subject, the soils are a *mass of salts*, mostly silicates, silicic being the most abundant and most powerful acid in nature. We should expect, from the composition of the simple minerals which form the rocks, that the soils, considered chemically, would be a mass of silicates. But it will be a more practical view, and better accord with the general representation of agricultural writers, to describe silicic acid among the earths, alumina, lime and magnesia. We have already described these earths, in their principal chemical characters and in their relations to the rocks. We come now to consider them agriculturally, and shall notice their amount in soils, their relations to the vegetable kingdom, and their fitness to perform the duties assigned them in the vegetable economy.

When soils are examined by chemical analysis, they are found to be composed of the following mineral substances.

1. *Silica* or *silicic acid,* also called silex and siliceous earth, constitutes about 40 or 45 per cent. of the crust of the globe, and 66 per cent. of all the rocks and soils of New England. This proportion varies but slightly, with regard to all soils,

capable of sustaining a healthy vegetation, with the exception, perhaps, of limited portions of calcareous and peaty soils, in which the proportion is much less, but generally greater than 66 parts in 100.

The properties of silica render it well fitted to form so large a portion of the soil. It is nearly insoluble in water, and hence is not liable to be washed away by rains. In fact it is not dissolved by any acid found in the soil, unless it be the crenic and hydrofluoric, in which state it may be introduced into the organs of plants. Silica is not an acid, by the chemical tests, because of its insolubility. It however combines with the alkaline bases, with the earths and metallic oxides, and is the most powerful *electro-negative* element in the composition of the soil. It acts in the soil as an acid, and balances, by its negative character, almost the entire mass of the *electro-positive* earths, alkalies and metallic oxides. Its power of absorbing and retaining water, is very slight, and hence when it is the principal ingredient of a soil, it imparts to it a porous, dry and light character. *The relations of silica to vegetation* are highly interesting. It is almost the only ingredient of soils which gives to them the property of permitting the roots of plants to extend themselves in all directions, and forms as we have seen, p. 175, a part of the vegetable structure. Silica thus furnishes the principal support to the cultivated grains and grasses, and defends them from the action of atmospherical and other agents.

2. *Aluminous earths.* Alumina, a sesquioxide of alumina, is composed, as we have seen p. 175, of 27.4 parts by weight of the metal aluminium, and 24 parts of oxygen. It is found in every region of the globe, and in the rocks of all ages. It results from the decomposition of the feldspathic minerals or argillaceous rocks. The different kinds of clay of which bricks, pipes and earthen ware are made, consist of *hidrate of alumina,* that is, of alumina combined with water, and of a small portion of silica. Aluminous earth is next to silica

in quantity, and constitutes but about 16 per cent. of all the soils in New England. It varies greatly in different varieties of soil, though it is never absent from any. Pure alumina, however, does not exist in the soil. It is generally combined with silica, and with organic acids, such as crenic and apocrenic acids, and geic or humic acid.

The properties of aluminous earth make it a fit associate for silica, in order to give the proper texture and adhesiveness to the soil. Like silica, it is insoluble in water. But its action upon the roots of vegetables, is just the opposite of silica, giving the roots their basis of action and support, and preventing them from penetrating too far. It retains the water with great force, but yields it to the plant as its wants may require. In consequence of its power of absorbing and retaining water, when it constitutes a large proportion of the soil, it is unfriendly to vegetation, forming a soft, ductile paste, which excludes the air in wet weather, and contracts and bakes in seasons of drought. As it contracts by heat, the delicate fibres of the roots are injured in the fissures thus formed, by exposure to the cold, heat and water.

Aluminous earth is still more nearly allied to vegetables by forming a part of their structure. The ashes of some plants contain very small portions of it. It is also found in the seeds of some grains. It is capable of acting the part, both of an acid and of an alkali, a circumstance which renders it probable, that its chief agency in the soil, is to act upon the vegetable matter, and convert it into vegetable food. Alumina is farther serviceable, from its possessing the property of absorbing gaseous bodies, such as ammonia, and of retaining in the soil for the use of the plant, what would otherwise escape into the air. The fermentation of manures in the soil, yield several gases, which are retained in this way.

3. *Lime.* Lime is also widely disseminated in nature. It forms the basis of extensive mountain ranges, and of a large portion of the cultivated surface of the earth. It exists, how-

ever, not in its pure or caustic state, but combined with acids, forming with carbonic acid the carbonate of lime (marble), which is the most abundant. In this form, it constitutes about $\frac{1}{7}$ part of the crust of the globe. The sulphate (common plaster) is next in abundance, and the phosphate is diffused through all soils, and is the source from which animals obtain their *bones*. The pure or quick lime is generally obtained by heating the carbonate in kilns, until all the carbonic acid is driven off. It will then unite with water, and form a white bulky *hydrate*, called slacked lime, used for mortar.

The quantity of lime, found in the soils of this country, is generally very small. From an analysis of the soils of Massachusetts, as contained in the report of Prof. Hitchcock, lime, in the form of carbonate, sulphate and phosphate, does not upon an average exceed 3 per cent. The sulphate is the most abundant, varying from 0.1 to 3.9 per cent.

The carbonate of lime, with the exception of one soil, in Truro, which contains 21.3 per cent. varies from mere traces of it, to 6 per cent.; but generally there is much less than 2 per cent., and not one soil in twenty, contains a single particle of lime in the state of carbonate. The amount of phosphate is not accurately determined, but the proportion in most soils is less than 1 per cent. The soils of Rhode Island, according to the analysis of Dr. C. T. Jackson, do not, upon an average, contain 1 per cent. of all the salts of lime, and scarcely 1 per cent. is found in the soils of New Hampshire.

Soils from the Western, Middle, and Southern States, although from lime-stone regions, rarely contain a larger proportion of lime, in any form than is found in New England. It appears from an analysis of five specimens of soil from Illinois and Ohio, that all the salts of lime amounted, upon an average, only to 4.9 per cent.

In other countries, soils are frequently described, containing from 6 to 30 per cent. of the carbonate alone. In this respect, then, our soils are peculiar, and hence the great importance attached to this substance as a manure. (See improvement of the soil.) The reason why so small a quantity of carbonate of lime is found in our soils, compared with those in other countries, is ascribed by Prof. Hitchcock to the fact that growing plants abstract it, and that our lime rocks are not so easily reduced to the state of soil by the ordinary agents of disintegration.

The influence of lime upon growing vegetables is not, in this country, due to the texture which it gives to the soil, for in most cases, the quantity is not sufficient to render a heavy soil light, or modify the influence of too great a quantity of siliceous sand. Its influence is probably threefold. 1. It tends to convert the vegetable matter into vegetable food, thus performing the office of a solvent, or converter of innutritious matter into nutriment. 2. It corrects the acidity of soils, by uniting with free acids, or decomposing poisonous, metallic salts. 3. It forms a part of the vegetable structure, and is properly inorganic food. Like all other alkalies it also contributes to electrical effects, which may be regarded as a kind of stimulus to the vital functions. It is found, as we have seen, in the vegetable productions, sometimes united with organic, and at others, with inorganic acids.

4. *Magnesia.* Magnesia is found in serpentine in the form of a silicate, in steatite or soap-stone, talcose slate, in magnesite, sea water, certain limestones, called *magnesian* limestone or *dolomite.* Although generally found in soils, it never constitutes but a small portion of them. The quantity is given in but a few of the soils of Massachusetts, and varies from .25 to 2½ per cent. from which it is inferred, that only traces of it exist. In the soils of Rhode Island, the amount of magnesia is rarely 1 per cent.; often none at all, or only traces are found. A few soils contain 4 per cent. In New Hampshire less than 1 per cent. is found, and in Maine, out of thirty-five soils analyzed, only one contained

any magnesia, and that contained 3 per cent. It must, however, exist in all fertile soils, as it enters into the composition of many varieties of grain. The kernel of corn could not be formed without the presence of the phosphate of magnesia. Magnesia, like lime, does not generally constitute a sufficiently large portion of the soil to affect its texture. When it does it has the properties of clay, absorbing moisture and imparting its adhesive properties. It acts as an alkali, to convert vegetable matter into food, and constitutes a part of the vegetable structure. When applied in its caustic state, it has been found injurious to vegetation; but as a carbonate, it is highly useful. Like lime, it must be regarded as an improver of the soil, as a manure, rather than an earth.

The union of these four earths in a soil, give to it generally the properties of each. But as they are combined in the soil with each other, and with other substances, in the form of salts, we cannot infer with certainty the exact character of the soil, by knowing in what proportions they exist; but we must know in what state of combination they are found. It will be seen that silica and alumina constitute almost the entire mass of the earthy ingredients of all our soils, and the qualities of a good soil will depend upon the right proportion of these substances. But there are other inorganic bodies found in soils, as essential to fertility as any that have been described.

2. *Alkalies and metallic oxides, contained in the soil.* The most important, and almost the only substances under this head, are ammonia, potash, soda, oxide of iron and manganese.

Ammonia has been shown by Liebig to exist in the atmosphere, in very small quantities; of course, in consequence of its solubility in water, it is found in all soils. It has been supposed, that ammonia was a product of the putrefaction of animal and vegetable substances, containing nitrogen. But Liebig believes, that it belongs to the original formation of the matter of the earth, and Daubeny points out its source as proceeding from volcanic action. The exact amount in the atmosphere or the soil has not been *accurately* determined. It is found in iron-rust, clay, etc., and is retained in the soil in the form of sulphate, carbonate, humate, etc.

Its relations to vegetation are of the highest importance. According to Liebig, it is the only source of the nitrogen of plants. Others regard it as the solvent of geine, and the converter of the vegetable matter into food; and some add, that it stimulates the functions of plants. Its action has already been considered in the third chapter.

Potassa or *potash*. Pure potassa is not found in soils. It is a well known alkali originating from several rocks, in which it exists mostly in combination with silicic acid (*silicate of potash*), but it is also found combined with several other acids.

The minerals which supply potash to plants are numerous and widely diffused. All the aluminous minerals contain it. Feldspar, a constituent of granite, contains 17¾ per cent. Basalt contains from ¾ to 3 per cent., clay-slate from 2.75 to 3.36, and loam from 1½ to 4 per cent. Hence we should expect to find potash in large quantities in the soil; but owing to the action of growing plants which eliminate the potash, soils which have been cultivated for some time, contain much less than might appear from its abundance in the rocks. This is a case, in which analysis must be resorted to, in order to determine the exact amount of an ingredient. In the recent analysis of the soils of New England, we have been unable to find potash as an ingredient, although it must exist in all our soils in a greater or less quantity, locked up in the minerals. Dana estimates its amount in the soil, composed of granitic sand, to be 36 tons per acre, 6 inches in depth. In some soils, it is found to constitute from 5 to 10 per cent.

The relation of potash to vegetation is similar to all alkaline substances. It is a powerful converter of vegetable matter into the food of plants. It neutralizes acids, and, by uniting with silicic acid, forms the outer covering or epidermis of the grains and grasses. It is found in all plants in considerable abundance, and is one of the greatest fertilizers of the soil. Plants, as we have frequently remarked, eliminate it from the rocks by galvanic action ; decomposing vegetable matter also abstracts it ; the ordinary action of the air, water, and many other agents: hence the use of clay, ashes, of fallow crops, and ploughing in green crops, to induce the soil to yield its potash.

Soda, as we have seen, is a constituent of many minerals, such as albite containing 11.43 per cent., mica containing from 3 to 5 per cent., and basalt from 5 to 7 per cent. of this alkali. But the proportion in the soil is much less, in consequence of the action of growing plants,—many of which take up and appropriate it as food. Common salt is a chloride of sodium, and is found very widely diffused, so that this alkali exists probably in sufficient quantities in the soil to supply all the wants of plants. Its action is similar to potassa, but it is not so essential to vegetation. Porphyritic soils contain it in the greatest abundance.

Oxide of iron exists in the soil as a protoxide, peroxide and in combination with acids. It is found in all soils, in one or all of these forms. The use of clay has been supposed to result from its containing from 9 to 13 per cent. of this substance. It is also found in green sand in great abundance, constituting about $\frac{1}{6}$ part of the whole mass. In fact, it is widely diffused through all the primitive and most of the secondary rocks.

The quantity of oxide of iron as determined by analysis, varies considerably in different soils, from 1 to 5 per cent. in the soils of Massachusetts. The soils of Maine contain from 2 to 12 per cent., those of Rhode Island from 2 to 8 per cent., and generally soils contain at least 5 per cent. of this oxide.

The protoxide of iron is generally unfavorable to vegetation, but the peroxide seems to act the part of an alkali, converting the vegetable substances into the proper state to be absorbed by the roots of plants, while the protoxide does not. Dr. Dana says, that if "iron *peroxidates itself in contact with vegetable fibre, the texture of the vegetable fibre is weakened, and geine* is produced, and that *in a few hours. It is during the passage from protoxide to peroxide, that the 'saponifying' action takes place*, geine is produced, and then *combines with the peroxide.*"

Oxide of iron is also found in the vegetable substance, and must be carried there in some of its combinations with acids, as the oxide is insoluble. It probably combines for this purpose, with some of the organic acids in vegetable mould, such as crenic or humic acids, or both, and thus acts the part of a base to those acids, which are the products of the living principle.

Crenate of iron and of alumina are deposited in iron tanks where river water runs. Liebig regards the oxide as performing the office of absorbing and retaining ammonia.

Oxide of manganese. But very small quantities of this oxide are found in soils, and still smaller quantities in plants. It probably acts in a manner similar to oxide of iron, forming a base for the combination of the humic or crenic acids.

3. *Salts* and *Urets.* Under this head, are included several compounds which analysis has detected in soils. Such as common salt, sub-phosphate of alumina, phosphate of lime, nitrate of potash and of soda, sulphate of lime, sulphate of iron (copperas), sulphuret of iron, etc. Some of these substances have received attention in other places, and but a few remarks are required to show what is most important to be noticed respecting them.

Common salt, or chloride of sodium, constitutes about 2½ per cent. of sea-water. It also exists in the rocks, especially in the new red sand-stone. It seems to act as an alkali, by furnishing soda to plants. The quantity in the soil is exceedingly small, but only small quantities are wanted. The chlorine, which plants sometimes exhale, must come from this substance. It is highly useful on some soils.

Sub-phosphate of alumina and *phosphate of lime* may be noticed here in connection, because they have lately been shown to be present in all fertile soils. Phosphate of lime is the most common form in which both the lime and the phosphoric acid exist.

It is from these substances, that animals obtain their phosphorus. About 50 per cent. of bones is phosphate of lime. Almost all the vegetable products contain it, whether the land has been cultivated or not. It even exists in the pollen of the pine in forests.

Nitrate of potash and *nitrate of soda* are sometimes detected in soils.

Sulphate of iron is also detected in a few soils, and is highly poisonous in its effects. Lime converts it into gypsum and oxide of iron, thus rendering it a valuable saline manure.

Sulphuret of iron is found in considerable quantities, but by exposure to air and water, it changes, first to the sulphate of iron, and then, by the action of lime, to the sulphate of lime, as above.

Carbonic acid in a free state is also found in soils, the quantity varying with circumstances. The action of this acid has been fully discussed. One fact of a highly practical value is, that the *urets* are constantly becoming *salts*, so that the soil is often found to contain a larger quantity of salts than the rocks. The process of disintegration produces changes in the arrangement of the simple elements.

Thus we have enumerated all the inorganic bodies, which are found in the soil, as ascertained by analysis, and their general relations to growing plants. From this examination soils are composed, generally, of the

Earths,			*Alkalies,*		
Silica	66.	per cent.	Potash	2.	per cent.
Alumina	16.	"	Soda	.5	"
Magnesia	1.	"	Ammonia	.5	"
Lime	2.	"			
Oxides,					
Of Iron	5.	per cent.	*Salts* and *Urets,*	1.5	per cent
Of Manganese	.5	"	*Organic matter,*	6.5	"

II. *Organic constituents of the soil.* A proper mixture of organic matters with the mineral ingredients, is essential to the fertility of the soil, and hence vegetable or animal substances are always found in soils capable of cultivation. These organic matters are derived from the roots and other parts of plants, or from the application of manures. The substance which is formed by the decay of these organic products, and which has been supposed to give fertility to the soil, is called by several names, as *humus*, *geine*, vegetable mould, etc. and is intended to include all the decaying organic matter of the soil. It is a brownish or black substance, and when it becomes intimately mixed with the mineral ingredients, it imparts a black color to the soil, a greater power of absorbing water and gaseous substances, renders it more permeable to air and to the roots of plants, improves its texture, and increases its power of absorbing and retaining heat.

This remarkable substance, a history* of which has already been given, p. 138, is composed, as we have seen, of the following substances: *humin*, extract of humus, humic acid, crenic and apocrenic acids, which are generally combined with the bases, lime, magnesia, soda or potash, ammonia, alumina, oxide of manganese, and per-oxide of iron. When therefore we examine the organic constituents, by analysis, we find the following substances.

1. Humic acid, which is identical in composition with hu-

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* Dr. Dana, in his Muck Manual, has given a history of this substance, and advocates the use of the term *geine*.

min. The quantity of this acid, contained in any given portion of soil, may be determined, very nearly, by the proportion of vegetable matter, dissolved by the application of alkalies.

The following is the proportion of the soluble matter, called *soluble geine*, nearly identical with humic acid, and of insoluble geine (humin), contained in the soils of Massachusetts, from the different geological formations.

		Soluble Geine.	Insoluble Geine.
Alluvium		2.25	2.15
Tertiary argillaceous soils		3.94	5.22
Sandstone	"	3.28	2.14
Graywacke	"	3.60	4.00
Argillaceous slate	"	5.77	4.53
Limestone	"	3.40	4.04
Mica slate	"	4.34	4.60
Talcose slate	"	3.67	4.60
Gneiss	"	4.30	3.40
Granite	"	4.05	3.87
Sienite	"	4.40	4.50
Porphyry	"	5.97	4.10
Greenstone	"	4.56	6.10

The soluble geine, of course, is not all humic acid, as other acids and salts are dissolved by the alkalies; still, there is not much reason to doubt, but that there is from 1 to 3 per cent. of this acid in all fertile soils.

2. *Crenic acid* was first discovered by Berzelius, in 1832, in the water of Porla well, near Orebro, in Sweden. It exists in all our soils, and in the waters of rivers and ponds, and is generally associated with apocrenic acid, and combined with bases.

Both of these acids may be precipitated from their neutral solutions by means of subacetate of lead, and may be separated from each other by the salts of copper.

It is difficult to determine the quantity of this acid. Soils, analyzed by Berzelius, contained two per cent.

The crenic acid has been detected in the sub-soil, and this may account for the utility of sub-soil ploughing. It is also found in river water, and may account for the effects of irrigation. The compounds of crenic acid, described p. 136, are also found in small quantities in the soil.

Apocrenic acid is formed, as its name imports, from the *crenic*, by simply exposing the latter to the air. It was found in the water of Porla well, in connection with the crenic acid. This acid is found in very small quantities; in some soils, according to Berzelius, about two per cent.

As all the alkalies dissolve these two acids, and as the alkaline earths render the inert crenates active, we can see the utility of adding alkaline substances to the soil to act upon these acids, and to bring them into a fit state to enter the vegetable organs.

"The remarks of De Saussure on soils," says Berzelius, "seem to show, that the three constituents above described, crenic, apocrenic and humic acids, by means of the reciprocal influence of water and air, become mutually changed. Water in moist soil, changes a part of the insoluble humin into humic acid; so that, after a sufficient length of time, the greater part of the humin becomes *soluble*. The atmosphere, on the other hand, re-forms, from the soluble matter, humin. Coal of humus, which in contact with the air changes a portion of it into carbonic acid, is itself converted into humin and humic acid, and this appears in fact to be the useful effect of loosening the soil by tillage which exposes it to the influence of the air."

The extract of humus and *glarin* are brown matters, mostly composed of carbon, hydrogen, and oxygen; and, so far as we know, are of little use to vegetation, in their pure state. They may furnish matter for nutriment, after being acted upon by the air or alkalies.

Dr. C. T. Jackson states, that the substances which are confounded under the name of *soluble humus, soluble geine,* etc. consist of several substances already referred to. Dr. Dana calls the whole *geine,* and as the fertility of a soil depends upon the *soluble geine* and *salts,* his method of analysis is well adapted to determine their amount, and the consequent fertility of the soil.

But whatever views are adopted, relative to the nature of the organic constituents of soils, the fact is fully established by experience, that a due mixture of organic, with the mineral ingredients, is essential to fertility, and that the power of the soil to bear successive crops for a series of years, depends upon keeping up the supply of humus and salts, which a continued course of cropping takes away. Other substances must exist also in the soil, in a state of partial decomposition, such as the various vegetable products, but they all finally pass into those above described, or pass off in gases, such as ammonia, sulphureted hydrogen, and carbonic acid.

Sect. 3. *Theory of the mutual action of the inorganic and organic constituents of Soil, and of growing Vegetables.*

The different earths, acids, salts and organic matters, described in this section, are combined in the soil with each other in definite proportions. They are constantly subjected to the laws of affinity, and as this power exists in different degrees of force in the different compounds, there are frequent and almost constant changes going forward. These changes are aided by the influence of the atmosphere, water, temperature, etc., and tend to alter the relative proportion of the different compounds. The agents concerned in converting the rocks into soils, continue to act, and the same changes continue. These changes are those produced by the *mutual action of the organic and inorganic constituents,* and those which are produced by the *agency of the living vegetable.*

I. *Action of the organic and inorganic elements of soil upon each other.* The elements of soil, as we have seen, are distributed into three classes; *silicates*, that is silicic acid united to the several bases, as in the simple minerals; *salts*, such as phosphates, carbonates, etc.; and *humus* or *geine*, which may include all the organic portions.

1. The silicates appear to act but slightly if at all upon each other, and hence, were there no agent external to them, would remain without change for ages. But the carbonic acid of the air combines with the bases of the silicates, the potash and soda, and forms soluble salts. These are removed by water, and the silica and alumina remain. By this action, the soil is rendered gradually and constantly finer, more clayey and tenacious.

2. The earthy carbonates, such as limestone, act in the same manner upon the silicates as carbonic acid, hence the utility of lime to set the alkalies and oxides free.

3. The alkaline bases potash, soda, lime, magnesia and alumina, which are thus set free, combine with the humic, crenic and apocrenic acids, or, according to Dana, with the geic acid and form *geates*, which are converted into soluble super-geates, by the action of carbonate of lime.

4. These bases not only combine with the geic acid, but they act by their presence or catalytic power; and convert insoluble into soluble *geine*. The power of hastening decay, is greatest in potash and lime, next in alumina, and finally in oxide of iron while passing from the protoxide to the peroxide, hence the utility of these substances in rendering the vegetable matter soluble and available to the roots of plants.

5. The oxygen of the air and of the water hastens the process of decay, and by liberating the carbonic acid, tend to keep up the process of decomposition.

II. *Mutual action of growing plants, silicates, salts* and *geine*. The action of salts and silicates upon each other, even when aided by the humus of the soil, is not very rapid. But when a living plant is introduced into the soil, it exerts a catalytic power, and causes the salts and silicates to form themselves into new compounds. Life imparts activity to all the chemical agents. It lets loose the bases of the salts upon the vegetable matter, and they convert it into geine. The liberated acids act upon the silicates and form new salts, ready to be decomposed by the vital power, and to enter the living organs, or to act again upon the inert *silicates* and insoluble vegetable matter, and render portions of them active. It is in this way, that a small quantity of salt introduced into the soil, will continue to reproduce itself, and hence the surprising effects which are often witnessed, when salts in small quantities are added to the soil.

1. The general theory then, of the action of salts, may be thus stated: *The bases of salts, whether alkali, alkaline earth*, or *metallic oxide, act exactly alike*; that is, (1) They act continually upon the organic matter of the soil, rendering it soluble and capable of entering the organs of plants. (2) They are taken into the plant, either in combination with their mineral acids, and decomposed by the organic acids, or eliminated directly by the vital force and assimilated. In the latter case, the acid of the salt acts upon silicates as above, and reproduces the same salt.

2. It will be seen, that if the salt is a carbonate, the carbonic acid will act with great power upon the silicates. If it is a phosphate or nitrate, both the acid and the alkali are nourishers, and the effect will be much increased. But if the salt is a sulphate, or a hydrochlorate, then the acid will not produce so good effects, and may be poisonous and highly injurious, hence the *character of the acid determines* the character of the effect, or, as it has been expressed, peculiarity of action depends upon the acid and not upon the *base* of the salt. This is substantially the theory of Dr. Dana. It throws more light on the action of salts, than any which we have seen. It will be further illustrated on the subject of manures.

SECT. 4. *Circumstances upon which the Fertility of Soil depends.*

Having in a previous section, given the mode of analysis, by which the substances which have been described are obtained, this section will be devoted to an examination of soils, with a view of ascertaining, if possible, the reason or source of their fertility. This will enable us to understand those various methods of improvement which will be hereafter described.

In order therefore, to give a *practical value* to the various topics treated of in this chapter, it will be necessary to make some calculations, as to the absolute quantity of the various ingredients in the soil, that we may infer what the soil requires, as a condition of fertility. The first example which we will introduce for this purpose, is the analysis by Berzelius of two soils, from Russia and Siberia.

A, soil never cultivated. B, long cultivated, and said to be in an exhausted condition. C, sub-soil of the field B.

		A.	B.	C.
Aluminous matter,	Sand,	51.84	53.38	52.77
	Silica,	17.80	17.76	18.65
	Alumina,	8.90	8.40	8.85
	Perox. of iron,	5.47	5.66	5.33
	Carbonate of lime,	.87	.93	1.13
	Magnesia,	0	.77	.67
	Water,	4.08	3.75	4.04
	Phosphoric acid,	.46	.46	.46
	Crenic acid,	2.12	1.67	2.56
Acids combined with peroxide of iron & alumina,	Apocrenic acid,	1.77	2.34	1.87
	Humic acid,	1.77	.76	1.87
	Extract of humus,	3.10	2.20	.00
	Humin and rootlets,	1.66	1.66	1.66
		99.84	99.86	99.86

It will be seen by inspection of these soils, that they do not differ in the quantity of silica, alumina and oxide of iron. The difference in fertility, therefore, is not due to these ingredients. Let us examine further, and see if we can discover the true cause of it.

The soil A, which has never been cultivated and which was the most fertile, has the greatest quantity of crenic and humic acids, but the soil B, which has been exhausted, contains less than 1 per cent., although it contains a greater quantity of apocrenic acid than either. This acid, however, and its salts are supposed to exert but little influence in vegetation. C, the sub-soil of B, appears to have received nutritious matter from the soil, and would doubtless yield a larger crop than the soil itself. Here, then, we have developed two important facts: 1. That the fertility of a soil depends upon the humic and crenic acids. 2. That fields long cultivated and almost exhausted, may be rendered fertile by subsoil ploughing.

It may be further seen, that lime, a substance essential to fertility, is most abundant in the sub-soil, having been carried down from the soil in combination with humic and crenic acids. This is another mode by which the soil becomes deprived of lime and alkali.

The second example we will instance, is that of three soils from Rhode Island, analyzed by Dr. C. T. Jackson.

The three specimens were originally of the same character. A, soil in its natural state, that would not produce more than 10 bushels of corn to the acre, less of other grain, and no hay. B, has been improved by ashing only, and produces 1½ tons of clover. C, is in a high state of cultivation, and has produced, in a three years' rotation, 60 bushels of corn, 50 of oats, and two tons of hay per acre.

The coarser pebbles and vegetable fibres were all taken out by sifting the soil through a fine sieve, and 100 parts of the fine materials were subjected to analysis.

	A.	*B.*	*C.*
Water of absorption	1.80	2.20	1.55
Soluble vegetable matter	2.50	1.60	4.60
Insoluble vegetable matter	2.00	2.15	1.50
Peroxide of iron	2.10	2.50	2.07
Alumina	2.10	2.75	1.39

Magnesia	1.00	traces.	
Phosphate and crenate of lime		1.20	traces.
Insoluble silicates	88.20	88.20	89.10
	99.70	100.60	100.21

Inspection of these soils will show the cause of the different degrees of fertility. The soil A, which was the poorest, contains of soluble vegetable matter, 2.50 per cent. The soil B, next in fertility, contains 1.60 per cent., most of the soluble matter having been removed by the agency of the ashes, with the crop; while the soil C, in the highest state of fertility, contains 4.60 per cent. of *soluble vegetable matter.* This alone is sufficient to account for their difference. In fact, in all other respects, they are *all nearly alike.* Now this soluble vegetable matter, is composed of humic and crenic acids, or their salts, the very substances which it is generally believed are the nutritious portions of the soil. On Liebig's theory, such a result is perfectly inexplicable.

A third example is of two soils analyzed by Prof. Hitchcock, according to Dr. Dana's rules; one, A, from Lazelle county, Illinois, and never cultivated, and the other, B, from Sciota Valley, Ohio, and cultivated 14 years without manure.

	A.	*B.*
Soluble geine (humates and crenates)	7.6	4.5
Insoluble geine (humin, etc.)	13.8	6.7
Sulphate of lime	18.4	2.1
Phosphate of lime	0.4	0.9
Carbonate of lime	3.3	2.8
Silicates	73.5	83.0
Water of absorption	9.5	5.3
	106.1	105.3

Both of these soils are of the first quality. The quantity of soluble geine is large, and also the amount of salts. But the difference between that which has been cultivated, and that which has not, developes one of the most important facts in the whole science of agricultural chemistry; a fact, however, which has constantly made its appearance in these analyses, viz. that the quantity of *soluble geine* in the soil A. is nearly double of that in the soil B, and the *insoluble* geine is more than *three times* the quantity. What inference is more obvious or certain than this, that the cultivation of the soil removes its soluble geine and favors the conversion of the insoluble portions into those which are soluble; and that vegetable matter is not added* to the soil by cultivation, but abstracted from it, and unless this is supplied, the land will, in time, become exhausted and consequently barren. Thus it is that theoretical deductions confirm actual experience.

These results are confirmed by the analysis of the soils of Massachusetts; and hence, Dr. Samuel L. Dana of Lowell has proposed and advocated a theory of great practical importance to the farmer, that the mineral ingredients of the soil are of little importance, but that *salts* and *geine* (soluble vegetable matter) are the sources of fertility in all soils. The great object of analysis is to ascertain the condition of the organic matters in the soil, and the means of improvement, viz. the conversion of *insoluble* into soluble *geine.*

There are facts which show, that alkalies are equally important with geine, and the labors of Dr. Dana and Prof. Hitchcock establish this fact beyond a doubt. Liebig attributes to the alkalies and salts a less extensive, but more direct agency, in producing fertility, than has generally been supposed.

The amount of alkalies is given in only a few soils whose analyses have fallen under our notice. But as the alkalies are found in plants, and exert a powerful influence in vegetation, it may be interesting to make some few calculations as to their amount, in order to see if they are in fact essential to fertility. In making these calculations, we will give the ab-

* Unless it is in wood lands or peat meadows, in which case large quantities of vegetable matter are derived from the atmosphere.

solute amount of all the ingredients of an acre of soil, of a tillage depth of six inches.

In order to show distinctly the influence of alkalies and alkaline earths, let us first estimate the amount, in a soil composed of the same materials as the rocks, allowing the soil to be of the same composition as our ordinary granite, $\frac{2}{5}$ quartz, $\frac{2}{5}$ feldspar, and $\frac{1}{5}$ mica.

1. Supposing a cubic foot of such soil to weigh 125 lbs., 1 acre of tilled surface, 6 in. in depth, would weigh 1361.25 tons.

Of this there is of silex	74.84 per cent.	=	1018.76	"
Alumina	12.80 "		174.23	"
Potash	7.48 "		101.82	"
Magnesia	0.99 "		13.47	"
Lime	0.37 "		5.03	"
Oxide of iron	1.93 "		26.37	"
Oxide of manganese	0.12 "		1.63	"
Fluoric acid	.21 "		2.85	"

2. In sienite rock, hornblende takes the place of mica, 1 acre of tilled surface 6 in. in depth, would weigh 1361.25 tons.

Of this there is of silex	74.84 per cent.	=	1018.76	"
Alumina	9.79 "		134.27	"
Potash	6.78 "		92.29	"
Lime	2.76 "		37.57	"
Magnesia	3.76 "		57.18	"
Protoxide of iron	1.46 "		19.87	"
Protoxide of manganese	.04 "		.54	"
Fluoric acid	.03 "		.40	"

No allowance is made here for vegetable matter, and the specific gravity exceeds that of soils which contain it, and which are in a finely divided state and therefore more bulky, but the amount of potash, lime and magnesia is enormous, compared with the same substances in soils which have been cultivated. Here is 100 tons of potash on an acre of soil, or of rock six inches in depth, while in the soil of Massachusetts, the fine materials, separated from the coarse pebbles, according to Prof. Hitchcock, contain no potash in a free state, and probably but a small quantity in any state. What becomes of this alkali? We know that it enters into all vegetables, as it is found in their ashes, and with them has been removed from the soil. It will be found that the alkaline substances, lime, and magnesia, are also abstracted in a similar way, and hence, as a practical deduction, soils generally need to have these alkalies added, that their fertility may be kept up. It is rarely the case, that the potash becomes wholly taken from the soil, but it is locked up in the minerals, and is not exhausted until they are all decomposed. Liebig asserts, that the soils of Virginia, from which harvests of wheat and tobacco were obtained for a century, became exhausted, because their alkalies were all removed, or so large a quantity of the free alkali, that the annual disintegration did not furnish a sufficient quantity to supply the wants of the crop. The amount of alkalies, as estimated per Hessian acre,* removed in the space of 100 years, is 1,200 lbs. mostly of lime and potash. But generally, the soil contains enough potash, locked up in the minerals, to answer all the wants of vegetation. "A thousandth part of loam," says Liebig, "mixed with the quartz, in new red sandstone, or with the lime in the different limestone formations, affords as much potash to a soil only twenty inches in depth, as is sufficient to supply a forest of pines, growing on it for a century. A single cubic foot of feldspar is sufficient to supply a wood, covering a space of 40,000 square feet, with the potash required for five years."

It would be easy to show, that our forest granitic and gneiss soils, and even our pine plain land, contain sufficient potash and lime for all the wants of vegetation. But they are not in a free state, hence, although growing plants, by galvanic force, eliminate them from the minerals, still they are not returned to the soil because they are removed with the crop. If the plants were all turned into the soil,

* A little less than an English acre.

the requisite supply would be obtained. The most fertile soils contain alkalies in a suitable state to act, both upon the vegetable matter, and to enter the vegetable organs, and hence alkalies, especially potash and lime, are generally beneficial to the soil.

It will be seen, as a practical inference from what has been stated, that alkalies *may be added* to the soil, as the quantity needed is small. If it were required to add silica; the task of improving the soil would be utterly hopeless; but a single grain of lime or potash, in a hundred, is sufficient oftentimes to ensure fertility, *and it therefore appears, that alkalies as well as vegetable matters are essential to a fertile soil.* This conclusion may be rendered still more evident, by the following estimates of three fertile soils from the farm of J. P. Cushing, Esq. Watertown, Mass., in which the absolute amount of the materials are stated, according to analysis, by Dr. C. T. Jackson. The soil originated from granite, sienite and greenstone.

		A.		*B.*		*C.*	
	Insoluble silicates per acre, six inches tillage depth	664.045	tons.	597.601	tons.	669.943	tons.
	Alumina	35.219	"	30.390	"	21.695	"
	Perox. of iron and mang.	34.494	"	23.992	"	32.976	"
nate	Phos. and create of lime	4.311	"	2.399	"	7.376	"
*	Soluable vegetable matter	26.733	"	21.193	"	22.562	"
	Insoluble do.	54.329	"	69.177	"	73.763	"
ble	Magnesia			1.597	"	4.339	"
	Water	39.678	"	43.025	"	33.084	"
	Specific gravity	1.277	"	1.195	"	1.255	"
	Cubic foot weighs	79.181	lbs.	73.438	lbs.	79.688	lbs.

By estimates, like the above, it is obvious to any farmer, that the salts and vegetable matter may be supplied to the soil, and that the great object of improvement is to supply them.

It has been stated, that the mineral ingredients were of far less consequence than it was formerly supposed. This is true, yet it must not be inferred that they are of no importance at all.

Prof. Hitchcock has shown by an analysis of the soils of Massachusetts, that some of the most productive in the State contain *less* vegetable matter than those more barren. Although the proportion of soluble geine, compared with that which is insoluble is very great, (as these soils are the alluvial deposits of the Deerfield and Connecticut rivers,) it is chiefly the *fine state* of the mineral ingredients which will account for their fertility. They must be exhausted much sooner than other less fertile soils, and will of course require a constant supply of vegetable matter, to keep up their fertility.

A continued course of cropping improves the texture of nearly all soils. They gradually become finer, and must be deepened to supply the requisite quantity of decomposable minerals.

We will close this subject, by a general summary of the principles which have been developed, considered in their practical relations to our soils.

1. The first general conclusion is, that it is important to the farmer to obtain an exact knowledge of the ingredients of his soil, in order to make the required improvement. If a soil is not productive, analysis will show the reason, and point out the right mode of securing fertility.

2. Although the mineral ingredients of a soil are far less important than the humus and salts, yet it is well established, that a soil composed wholly or $\frac{19}{20}$ of silica, lime, alumina or magnesia, is entirely barren, hence sand or clay will not support vegetation.

3. Two kinds of earth are necessary to the fertility of any soil, viz. silica and alumina. But a soil does not attain its highest degree of fertility, unless there are added small quantities of lime, magnesia, oxide of iron and of manganese. At least, three earths are essential to the highest state of fertility. Plants require but a small quantity of these earths to enter into their constitution, therefore the proportions may vary

widely without any apparent effect, provided the texture be continued the same.

4. The fineness of the earthy ingredients is more important to fertility, than the proportions in which they exist; because the power of the soil to absorb water, and of the roots of plants to draw in nourishment, depend upon the fineness of the particles; hence it is found, that one earthy ingredient may be substituted for another, provided the electrical character of the soil is not changed. If, however, we are sure that a soil contains silica, alumina, lime and oxide of iron, it may be made fertile. We are sure of all but the lime, which exists in a small quantity in all our soils, and may be added generally without fear of injury.

5. But the most important substances to be attended to are vegetable matters and salts. Without these, soils are *absolutely barren*, however well constituted in their mineral portions.

6. Fertility depends not upon the quantity of *humus*, but upon its *state*. The greater the quantity of soluble geine (humates, crenates and apocrenates), other things being equal, the greater the fertility.

7. As salts are removed by continued cropping, they must be supplied from the rocks, or from a foreign source; hence their utility as a manure.

8. It may be inferred, that the best constituted soil contains the various ingredients in about the following proportions: silica 60 parts in 100, alumina 16, lime 3, oxide of iron and manganese 7, soluble geine 4, insoluble geine 5, potash 3, soda 1, magnesia 1. The earthy constituents may vary, but the salts and geine must be from 4 to 10 per cent., or the soil will not produce a bountiful crop.

9. Finally, those substances which our soils require to ensure fertility, are within the reach of all our farmers, and there is the best encouragement for all to seek them out and apply them. No excuse can be rendered if their farms do not

produce bountifully, if their own stores are not well supplied with all the necessaries and comforts of life.

Sect. 5. *Classification and Description of Soils.*

As all soils originate from the decomposition and disintegration of rocks, effected by the chemical and mechanical agency of air, water, and vegetation, to which small quantities of vegetable and animal matters are added, the most obvious mode of classification would seem to be that derived from the geological character of the rocks. For we should expect that soils would resemble the rocks from which they originated, and (with the exception of some cases of great disturbance by glacial action, or running water, in which cases several varieties of rock are mingled together), that the rock from which the soil originated would underlay it.* The fact too that we must look to geology, to ascertain those natural sources of fertility, which are so abundant and desirable in every country, renders some knowledge of this science abso-

* Dr. Dana in his Muck Manual, p. 20, has given as the third principle of agricultural chemistry, that "the rocks have not formed the soil which covers them." This appears to be true in a restricted and modified sense. The soil has been moved in *most cases* from the rock in place, but not always beyond the formation. There are many cases, where the soil is found to have originated *directly* from the decay of the underlaying rock. The second principle, "that rocks do not affect the vegetation which covers them," p. 11, seems to require a similar modification. There are many exceptions to the rule, and the truth would be as nearly expressed if the negative were left out. A case now occurs to me of the marked influence of the underlaying rock. There is a small belt of land in the southern part of Vermont, in which one ingredient is silicate of lime, and the vegetation is not only more flourishing in this formation, but the sweet grasses as clover are much more abundant, although the situation is high, and it is otherwise more unfavorable than the neighboring soils, which are less fertile. Hence, the first principle, that "there is one rock and consequently one soil," appears to be opposed, not only to the general opinion of writers on soils, but to direct observation.

lutely essential to an intelligent understanding and successful practice of agriculture as an art.

But as such a classification may not be intelligible to those who are wholly ignorant of geology, the more common classification of agricultural writers is added, in which no reference is had to the *geological origin*, but only to the *chemical character* of the soil. It will be seen that both modes correspond in many important particulars, and it is hoped, that the infinite importance of an exact knowledge of soils to the practical farmer, will be a sufficient apology for adopting a method which must necessarily lead to some degree of repetition. Perhaps we ought to urge this as a peculiar excellence, inasmuch as each mode will throw light upon the other, and enable the careful student to obtain a clearer and more comprehensive view of the subject, than either mode taken by itself.

Geological Classification and Description of Soils.

Geologists make two general divisions of the rocks: 1. *Stratified*, or those rocks which are found in regular layers, like the leaves of a book, and which appear to have been deposited from a mechanical and chemical suspension in water. 2. *Unstratified*, or those which have no marks of strata, but appear, from their texture and resemblance to the lava of volcanoes, to have once been in a fused or melted state. The stratified rocks are divided into Aluvium, Diluvium or Drift, Tertiary, Secondary and Primary. Each of these divisions are variously subdivided. The chemical distinction was pointed out page 187. Geologically, then, soils may be divided into the five following classes: Alluvial, Diluvial, Tertiary, Secondary and Primary soils.

I. *Alluvial soils.* These are of two kinds; those formed by rivers, and those resulting from peat-swamps, or growing vegetables.

1. *Alluvial soil of rivers* consist of particles of every kind

of rock, over which the stream passes. The water suspends large quantities of matter, which, in connection with the mineral ingredients, is composed of various vegetable substances. This is deposited at the mouths of rivers, or, when they overflow their banks, along their margins. This soil will be fertile or barren according to the character of the rock over which the rivers flow. Alluvial soil is generally the most fertile and desirable of all soils. It appears to owe its fertility to the fine state of its particles, or to its texture, and the condition of its vegetable constituents. For it is found, by analysis, to contain less of vegetable food than most other soils. But when rivers pass over sandstones, it often happens, that no vegetable matter is intermingled, and instead of fertility, nothing being washed down but silicious matter, we have heaps of barren sand. Most of the alluvial soils of New England and of the Western States are fertile; while many along the coast of the Southern States are barren plains.

The value of alluvial soil depends upon another circumstance. If the sub-soil is gravelly or sandy, the water, and with it, the manure passes down below the soil into the sub-soil. This kind of soil is the most easily recognized of any; and every farmer knows it, under the name of interval or meadow land. Its position also points it out, as it is generally found along the banks of rivers, and at their mouths. In the latter case, the ocean waves often throw it back mixed with marine exuvia upon the land, and form salt-marsh alluvions. The valley of the Connecticut river in New England, presents some fine examples of river alluvium; for example, the meadows of Deerfield, Hadley, Northampton, etc. But alluvial soils are much more extensive in the Middle and Western States, especially in the vallies of the Mohawk, Ohio, Mississippi and Missouri. In the West, it has received the name of *bottom land*.

2. *Peat alluvial soils.* Among the alluvial soils may be

ranked the *peaty soils*, which consist mostly of vegetable matter, partly decayed and partly in a state of preservation. This variety of soil is of every degree of texture and fertility. Some of the peat meadows and swamps contain pure peat, with a small quantity of mineral matter. In this case, they should be regarded rather as depositories of fuel and manure. But they can be made the most valuable of all soils, because they contain inexhaustible quantities of vegetable food.

Peaty soils, include all those in which are found large quantities of vegetable matter, in a partially decomposed state. A large portion of the peaty soils are left wholly barren, through want of chemical skill to bring them into the proper state for producing crops.

II. *Diluvial* or *glacial soils.** These are more extensive than any other. They seem to have resulted from the action of glaciers, when the position of the earth was different from what it is at present. They are composed of sand, gravel and rounded pebbles, which are mingled together and appear to have been moved, in a southerly direction from the rock out of which they were formed. In consequence of this transportation of the abraded materials, by glacial or some other action, the detritus of several kinds of rock are in some cases commingled. In others, the materials are not carried far beyond the rock from which they were formed; so that the extent of this division of soils is much less, than would otherwise appear.

Diluvial soils may be divided into three varieties; sandy, gravelly and argillaceous.

1. The *sandy* and *gravelly* diluvial soils differ only in the relative fineness of their materials. The most common varieties consist of course sand, and rounded pebbles. These are

* Called glacial soils because it is now pretty well established, that the diluvial or drift was formed by glaciers. (See Hitchcock's Report of the Geology of Massachusetts.)

the poorest of soils, especially when the pebbles and the sand are mostly from quartz rock. They form, to a great extent the *siliceous soils* of agricultural writers, and are generally warm and dry, without the power of retaining the manures which are placed upon them.

2. The other variety of the diluvial soils, the *argillaceous*, are exactly similar to those in the next class. They are formed of clay and sand, and are the opposite of the *gravelly diluvial soils* in their character, being heavy, moist, retentive of manures, and of water. They are capable, however, of being made the most fertile and valuable of soils; as they compose what are generally denominated *clayey*, and when long cultivated, *loamy soils*.

III. *Tertiary soils.* The tertiary rocks are alternate beds of sand, clay and marl, generally arranged in horizontal layers, and often not hardened into solid rock. The clays or argillaceous earths seem to have originated from the argillaceous minerals; of which feldspar, mica and zeolite are the principal. These, with the last described variety of the diluvial soil, answer to the description of *clayey soils*, although soils from the tertiary rocks include several varieties. The *argillaceous* in which clay predominates, and the *sandy* which resemble the soils of the diluvium, are two important divisions.

The tertiary beds, many of them, seem to have resulted from the filling up of ponds and lakes which were sometimes covered with fresh, and at others, with salt water; hence, they are often composed mostly of carbonate of lime, and are filled with fossil remains, especially of shell fish. But the more common variety of this soil is the *clayey*, and this varies from the stiff clays in which water and manures are retained for a long time, and which are generally cold, wet and unfruitful, to the *richest clay loams*, in which there is just sufficient alumina to give them body, and to enable them to support the roots of the grains and grasses, for which crops they seem best fitted.

The *sandy varieties* of the tertiary soil often consist of almost pure sand, laying directly upon beds of clay. They may be easily improved by deep ploughing, especially when the clay is not more than 6 or 10 inches below the surface. The sand and clay being mingled together, will improve the texture. The clay often contains carbonate of lime and oxide of iron; two indispensable substances to the fertility of any soil. But as most of the *tertiary soils* resemble those from other formations, they will be described under the head of *clayey soils*.

The *tertiary soil* is of limited extent in New England. It is confined mostly to the region of plastic clay. All the common clay-beds, and the soils resulting, are assigned by Prof. Hitchcock to the diluvium.

IV. *Secondary soils* or *soils from the secondary rocks*. The *secondary* formation includes a great variety of rock, and consequently a similar variety of soil. It would be useless here to point out all these varieties, as the chemical mode of classification will bring many of them together, as identical in composition, and in their agricultural relations.

1. The *cretaceous* or *chalky soil* is rarely found in this country, but is very abundant in England. (1) It consists of *calcareous earth* in the form of chalk or marl, mingled with flint, pebbles or concretions, and will be described under the head *calcareous soil.* When this soil covers chalk rocks it is white, and reflects the heat, hence it is often cold; but many varieties of it are very fertile.

(2) A second variety of the cretaceous soil consists partly of green sand, resembling chlorite or green earth mingled with sand. The green sand often contains large quantities of potash, and has been used in New Jersey as a manure with the most salutary effects. But this variety of soil, in this country, with the exception of New Jersey, does not generally contain potash.

(3) A third variety consists of blue marl clay, carbonate

of lime, with sand and fossil shells, which are derived mostly from the *gault* or *wealden* rocks. These resemble the clayey soils of the tertiary formation.

2. *Oolitic soil* is remarkable for the quantity of calcareous earths which it contains. It is derived from argillaceous limestones, clays and marls, and in consequence of the great quantity of fossil remains, is a very fertile soil.

3. *Saliferous* or *sandstone soil* is derived from sandstone rocks. It is composed of argillaceous, siliceous or calcareous matters, often highly charged with red oxide of iron, which gives to the soil a red appearance. It is, however, of every shade of color, and variety of texture and composition, varying from light sandy loams to stiff marly clays. The sandstone soil of New England is either colored red as in the valley of the Connecticut river, or gray. It is warm, dry and capable of being made very fertile. The rocks from which this soil is derived often contain gypsum and common salt, as at Salina, New York, and on this account favor the growth of those plants which require a large quantity of soda. Owing to its texture, it is particularly favorable to Indian corn, and the tap-roots, beets, carrots and turnips. The *magnesian variety* is much more retentive of water, and constitutes a very fertile soil.

4. *Carboniferous soil* is derived from three kinds of rock. 1. The shales of the coal beds, consisting mostly of argillaceous earth with vegetable remains and sandstones. 2. Carboniferous limestone, also called mountain limestone, which is so filled with the remains of small animals, *Enchrinites*, as to receive the name of enchrinal limestone. 3. The old red sandstone, which does not differ essentially from the red sandstone of the preceeding class. The soil will of course vary with the kind of rock.

5. *Silurian* or *graywacke soil* originates from an extensive class of rocks, under the name of graywacke, graywacke slate and shale. It is composed of sand, clay and calcare-

ous matter. The following are the principal varieties of this soil.

(1) The *conglomerate soil*, consisting mostly of coarse sand and pebbles which have been once cemented together, but are now crumbled into soil. The rock is known as *pudding stone* and is found in Roxbury, Dorchester, and many other places in the eastern part of Massachusetts. It is far the best soil found in this class.

(2) *Slaty soil*, of a gray color, more retentive of moisture and often clayey, but capable of being made very fertile.

(3) *Slaty red soil*, in which the rock and the soil is of a deep chocolate; in other respects it does not differ from the preceding. Sometimes these three kinds are mingled together, and when the coarse pebbles constitute the sub-soil, it is often subject to suffer by drought and to permit the manures to pass through, without producing much effect upon the crop.

As the coal measures repose upon the graywacke, it often happens that the fine graywacke soil becomes mingled with the carbonaceous clay slate, which renders the soil of a clayey texture.

4. *Clay slate soil.* This soil is similar to the preceding, but generally finer in texture and more argillaceous or clayey. It is the oldest of the secondary soils, and contains but few remains of plants or animals. The carbonaceous clay slate rocks when mixed with graywacke make a very fertile soil. It is black, retentive of moisture, and well adapted to grain, herdsgrass and clover.*

V. *Primary soils*, or *soils from the primary stratified and unstratified rocks.* This division includes a great variety of soils. The most common variety in New England, are argillaceous slate, limestone, mica slate, talcose slate, gneiss, granite, sienite and porphyry soils. The trappean varieties form a distinct class.

* See Jackson's Report of Geology of Rhode Island, p. 127.

Soils from the primary rocks are most abundant in New England. They are derived mostly from the decomposition or decay of granite, gneiss, mica slate, argillaceous, talcose, and hornblende slates. These rocks contain the ingredients of nearly all soils; silica, alumina, lime, magnesia, oxide of iron and of manganese, to which may be added the alkalies, potassa and soda. They are generally distinguished by the minerals which they contain, and which exist either in large or fine particles. The principal minerals are mica, feldspar and quartz. The mica is seen in thin shining scales; the quartz in angular or rounded pebbles, and the feldspar in white and earthy particles, more or less covered with oxide of iron, or vegetable mould. These ingredients may be detected by mixing the soil in water, agitating it a while, and pouring off the finer portions.

1. *Argillaceous slate soil* is derived from a rock well known from its structure, and from its use for the purpose of roofing buildings. It exists in very great perfection in Bernardstown, Mass. and Guildford, Vt. The color of this soil resembles the slate, which is dark brown, almost black. It is a poor soil in many places, especially where the rock approaches near the surface, but when the disintegration has proceeded to a greater depth, it is capable of being made a very good soil. It is composed almost entirely of argillaceous earth, mixed with a small quantity of silex.

2. *Limestone soil.* The primitive limestones which are interstratified with the slates, give rise to a variety of soil, which does not differ materially from the talcose and mica slate soil, as it appears from analysis, that some of them do not contain carbonate of lime in any considerable quantities. This may be due to the action of crops, or to the fact that the detritus of other rocks have been brought over them, and constitute their principal mass.

Some varieties of this soil contain carbonate of lime, others carbonate of lime and magnesia, forming the magnesian limestone soil. A third variety contains feruginous limestone, or iron combined with the lime, and the fourth variety contains silex or siliceous carbonate of lime. This latter soil is very fertile, and yields very sweet food for grazing.

The primary limestones differ from the secondary in being less friable and in containing no organic remains.

The magnesian variety from both the secondary and primary rocks is highly fertile, for although magnesia, in its caustic state, appears to be injurious to vegetation, the rock itself, when crumbled into soil, exerts no such effects; probably because it is already combined with carbonic acid.

The best test of a limestone soil whatever be its origin, is any dilute acid such as the sulphuric, in which case, the carbonic acid will escape with effervescence or with foam, when the soil is put into water, and the acid poured upon it.

The calcareous or limestone soil is of every degree of fertility, and is best fitted for wheat, clover and the sweet grasses.

3. *Mica slate soil*, like the rock, is composed mostly of mica and quartz. It is distinguished from clay slate soil, by its lighter color, yet these two rocks frequently pass into each other, and of course the soils are also mingled. In some cases the mica slate passes into gneiss and argillaceous slate, and the soil of course will partake of the character of both rocks. This soil is found in very many places in Worcester county, Mass. and in all the New England States, and is generally very fertile. It contains but little feldspar, and hence but little potash, but the mica yields a large quantity of magnesia, which gives it an adhesive and loamy character.

4. *Talcose slate soil* can hardly be distinguished from the mica slate by its color, although it is somewhat lighter. It contains *talc* instead of *mica*, and these may be easily distinguished; the former is non-elastic and of a soapy feel, the latter elastic and tough.

The *fertility* of this soil depends upon the mixture of other earths, such as clay. The argillaceous slate soil is quite productive, but generally this soil is more sandy and less fertile than that from mica slate.

5. *Gneiss soil* is very abundant in New England. It has a pale yellow color, and is sandy and gravelly, indicating by its appearance great sterility. This, however, is not always the case; the gneiss rocks contain large quantities of potash in their feldspar, as well as argillaceous and siliceous substances. These minerals when reduced to the proper degree of fineness make a very fertile soil. It is of two kinds, the *common* and the *ferruginous* gneiss soil. The latter is of a reddish color, in consequence of the peroxide of iron which it contains.

6. *Granite soil* does not differ essentially from gneiss. Both are composed of quartz, feldspar and mica, and of course yield all the mineral materials necessary to fertility. The granite soil differs in its texture from coarse gravel to fine sand. Dr. Dana regards all soils as composed essentially of "granitic sand," that is, just such materials as granite and gneiss rocks would produce by the ordinary process of disintegration. These rocks yield all the earths necessary to the highest degree of fertility. But their degree of fertility will depend upon their texture and the sub-soil. When they are underlaid with clay, or hard gravel, cemented together and made water-tight, they may be made very fertile, because they will then retain the soluble manures; but if the substratum is open gravel or sand, the soil itself gravelly or sandy, they are too easily drained of moisture, and permit the soluble manures to infiltrate or leach through them. Gneiss and granitic soils are better for Indian corn and grass than for the smaller grains.

7. *Sienite soil* differs from granite in containing hornblende instead of mica. Its structure is somewhat finer, and

its color darker than either of the preceding. It is also warmer and more favorable to cultivation.

8. *Hornblende rock soil.* Hornblende rock is composed chiefly of hornblende and compact feldspar, with variable portions of oxide of iron and of manganese, and the soil is composed of similar materials. The color is generally of a dark red-brown, of a fine texture, slightly adhesive when pressed in the hand, but not clayey. This soil contains a large quantity of oxide of iron, manganese and magnesia, the latter substance supplies the place of clay; the manganese, from its dark color and imperfect conducting power, renders the soil warm and highly fertile.

9. *Porphyry soil* is derived from the compact feldspars, which contain from 25 to 30 per cent. of alumina. The porphyry rock is among the hardest, but it yields rapidly to the agents of disintegration, and forms a very valuable soil.

VI. *Trappean soils* differ from the preceding by containing from 3 to 7 per cent. more of lime, magnesia and iron, and 20 per cent. less of silex.

1. *Greenstone soil* is often associated with porphyry. It is of a finer material, and more fertile. The character of these soils is often distinct, of a brown color, containing large quantities of iron. *Basaltic* soil is very similar to the above, but it is composed of augite and feldspar.

2. *Trachyte soil.* This is the soil from the ancient lava, and is found around volcanoes. It contains a large quantity of alkalies, which make it highly fertile. It is composed of glassy feldspar, hornblende, mica, titaniferous iron, and sometimes augite.

3. *Lava soil.* The more recent lava, when converted into soil, is often very fertile. It contains so large quantities of alkali, such as potash, soda, etc. that for some crops, it is the best of all soils. The two minerals, feldspar and augite, constitute nearly the entire mass of this soil. As these matters

are subjected to heat, there is a partial decomposition, and the alkalies are ready to act upon the crop.

The above enumeration contains the most important varieties of soil as derived from the rocks. They will be readily recognized by the practical geologist, and it is hoped that the farmer may derive some idea of their character and properties.

This geological classification, which is based chiefly on that proposed by Prof. Hitchcock, makes us acquainted with the soils as they stand related to the rocks. This is always useful and interesting, especially to the scientific agriculturist; but it is not so practical as the chemical mode of classification. It is to be hoped that the reader will, at least, examine this method and compare it with that which follows, that he may, as already remarked, obtain from both what could not be derived from either by itself.

II. *Chemical Classification and Description of Soils.*

We regard the geological classification of soils, as presenting the most enlarged view of the subject; but a more simple and practical method is to arrange soils according to their prevailing earths. These earths are silica, alumina, lime and magnesia. Hence those soils in which silex mostly predominates, are called *siliceous* or *sandy soils.* Those in which clay is in the greater proportion, are called *aluminous* or *clayey soils.* Those in which the carbonate of lime is the chief ingredient, *calcareous soils;* and when the lime is chalk, *chalky soils.* Magnesia, also, sometimes exists in sufficient quantities to give a name to the soil in which it is found. There is another class called *loamy*, which answers nearly to the more fertile alluvions, but results from a long course of cultivation, when large quantities of animal and vegetable matters are employed. The *peaty soils* are also sufficiently definite to form a distinct class. A short description of these soils, including the characters by which they may be recognized, their general mode of improvement, and their natural adaptation to the various crops cultivated by the farmer, may not be inappropriate.

1. *Siliceous soils.* In the silicious soils, from whatever class of rocks they are derived, silex or silica is the predominant earth. These soils originate generally either from the disintegration of silicious rocks, from glacial action, or from streams and rivers which pass over sandstone rocks.

Properties. Siliceous soils are either gravelly or sandy, or a mixture of both; they are always of a loose texture, permitting the water to pass easily through them.

They absorb but little moisture from the atmosphere, and part with it readily, on the application of heat. Hence in seasons of drought, they become mealy, and their vegetation is scorched and dried up. As sandy and gravelly soils do not generally combine with manure or vegetable matter, which is introduced into them, they easily part with it, and hence they have been denominated *hungry soils.* If the sub-soil is gravelly or sandy, they are subject to leaching, and the vegetable matter passes through them almost as fast as it is rendered soluble in water.

Sandy and gravelly soils are generally warm and quick, and from their want of adhesiveness, easily tilled. They differ from absolute barrenness to a high degree of fertility. When wholly without cohesion in their parts, they are entirely barren, and can only be made fertile by the admixture of other substances. This is the case often with the coarser gravels. When fine or sandy, and mixed with aluminous earth, or magnesia and a suitable proportion of organic matter, they become very fertile, especially if they have a tenacious sub-soil.

Mode of improvement. A sandy or gravelly soil may be improved by mixing clay or peat compost with them, so as to increase their adhesiveness, their power of absorbing water and of retaining manure. The stones should not be all removed, as they aid in retaining heat and moisture.

These soils are naturally better fitted for rye, barley and Indian corn than for wheat; but from their porous character, they are particularly fitted for those crops which are cultivated for the tubers of their roots, such as potatoes, turnips, beets, etc. For the tuberous roots, however, they must possess somewhat the characteristics of loam. They are also well adapted to timothy, clover and red-top.

2. *Aluminous* or *clay soils* are those in which clay in some of its varieties predominates. They vary in composition. Silica constitutes more than one half of their substance. These soils originate generally from the tertiary beds of clay, but are often formed by the disintegration of argillaceous rock, and by the agency of rivers, especially near their mouths, where the tides and waves throw back aluminous matter, which is either contained in the water in a finely divided state, or worn off from the cliffs of clay near the shores.

Aluminous soils are stiff and heavy, generally destitute of stones and very tenacious of water; of which they absorb large quantities, and yield it up with difficulty. When wet, they have the appearance of mortar, and adhere to the plough, when it passes through them. When dry, they break up into lumps when ploughed, or contract upon the surface, leaving small fissures crossing each other in various directions; hence, they are subject to the extremes of wet and drought. The clay soils differ in texture according to the quantity of other earths. A large quantity of *siliceous earth* renders them less cohesive; and if vegetable and animal substances are added, they often become similar to *loams*. They are naturally cold, especially when they are light colored, in which case they are not easily heated by the sun's rays. They are capable of uniting chemically with vegetable acids and earths, a circumstance of great practical importance, as it renders them very retentive of manures, so that in this respect, they are the opposite of sandy and gravelly soils. Clay soils are of every quality, from a dead, barren mass, to the rich clay loams, which are some of the most fertile and profitable soils which are cultivated. Hence their fertility will depend upon the proportion of other earths, the quantity of animal and vegetable matter they contain, and the character of the sub-soils. Common clay is wholly barren. Mixed with calcareous or siliceous earth, it is nearly so; but when, in addition, it contains large quantities of manure, it becomes comparatively fertile, if the sub-soil is sand, or such as to permit the water to drain off; but if the sub-soil is impervious to water, they are always cold, wet, and unfriendly to those crops which require the heat of summer to bring them to maturity.

The most fertile of these soils are the *alluvial clay* soils. These are formed at the mouths of rivers, where the sea exerts its influence upon the fine materials brought down by their waters, as they flow over argillaceous rocks. They often become mixed with animal and vegetable substances, and approach rich clay loams, of the most fertile and valuable quality. The common clay bottoms may be converted into fertile clay loams, by cultivation.

Mode of improvement. Aluminous soils are improved by admixture of siliceous and calcareous sand and peat muck. This renders them more friable and more easily tilled.

Sand often forms the sub-soil, in which case sub-soil ploughing may be resorted to, by which the sand and clay will become incorporated. This is different from trench ploughing, in which two ploughs are used, the one to turn the upper soil, and the other to bring up the sub-soil to the surface. But in sub-soil ploughing no portion of the sub-soil is brought to the surface, but merely loosened and pulverized. By this process, the air and water exert a fertilizing influence upon it, and then it is incorporated with the clay by trench

21

ploughing. If the sub-soil is similar to the soil in composition, the same process may be gone through, but in addition, the ground should be drained, to let the water pass off.

Crops. Clay soils are best adapted to wheat, timothy and oats; and where the bottom is dry, to potatoes and clover. Clay loams, containing carbonate of lime, are the best wheat soils known. This arises from the fact that they give stability to the roots, furnish the requisite alkalies, and absorb gaseous bodies, which are essential to that crop. They are not fit for the tap-roots, although such crops exert a favorable influence upon them by dividing the soil. They should be ploughed in the fall, to be broken down and pulverized by the frosts during the winter, especially if intended for an early summer crop.

3. *Calcareous soils* contain large quantities of carbonate of lime, under the varieties of chalk, marble, calcareous marl, siliceous, ferruginous and magnesian limestones. It is not necessary for a soil to be composed principally of this earth, in order to render it calcareous, a smaller portion of it being required to give the name, than of the other soils above mentioned. Calcareous soils originate from the disintegration of limestone rocks, which are most abundant in the secondary formation; especially from the chalk or cretaceous group. These soils are often washed some distance, and cover over large areas. Some of them contain fossils and some (as those from the primitive limestone) do not.

Properties. Calcareous soils are either gravelly or sandy, depending upon the degree of comminution. They are more adhesive and absorb more water than siliceous, and less than aluminous soils. But the most striking property is their power of causing the decay of vegetable matters, and of retaining several gaseous products for the wants of vegetation. Calcareous soil is friable and easily tilled; not suffering either from drought or too great moisture, provided the sub-soil is not too retentive of water.

Tests. Take a small quantity of the soil; heat it to 300° F. and then place it in a glass and cover it with pure water; drop on a few drops of hydrochloric acid; if bubbles of gas come up through the water it contains carbonate of lime. The pebbles will also show of what the soil is principally composed. The *chalky* variety is white, and reflects the heat more than the darker varieties.

Degree of fertility. Calcareous soils when combined with clay, with other earths and vegetable matters, are among the most fertile soils. If combined with siliceous sand and gravel, they are light, loose and often unfertile; but when combined with aluminous earth, they are the richest soils in all wheat-growing countries.

Mode of improvement. As pure calcareous sand or gravel is too friable and loose for the support of vegetation, it may be improved by adding clay-loam, or even pure clay; and sometimes sand and peat-muck, are highly valuable. Lime tends to exhaust the humus of the soil; large quantities of yard-dung or vegetable matter should therefore be supplied to keep up the fertility.

Crops. Tillage crops are best adapted to calcareous soils, such as peas, turnips, barley, clover, wheat and Indian corn. They give a peculiar sweetness to the grass which grows upon them, or rather favor the sweet grasses, and hence are excellent soils for pasture lands.

4. The *magnesian soils* which result from serpentine rocks, and magnesian limestones are very fertile soils, but not of sufficient extent to be further noticed in this place.

5. *Peaty soils* are composed of large quantities of vegetable matter mixed with earthy ingredients, lime, silica, alumina and oxide of iron. They abound in the eastern part of Massachusetts, and in most temperate regions of the earth.

Origin. These soils originate from growing vegetables, such as mosses in swamps where there is so much water that the roots, leaves and branches of trees accumulate, and are prevented from decomposition. In some cases a bed of several feet in thickness is almost pure vegetable matter, and becomes hardened into peat fit for fuel; in others, the texture is loose and spongy.

Properties. The properties of peat soils vary according to the character of the surrounding soils; where the earthy materials are clay they make a compact soil, retentive of water, and capable of being made very productive; when the earth is silica, they are more light and spongy, and permit the water to pass off. When mixed with calcareous matter they are reduced to a fine black mould; if the surrounding rocks contain *pyrites* they often become acid; if near the ocean, they become mixed with sea-salt. They sometimes contain bitumen. The properties therefore depend upon their texture, the earths with which they are combined, and the salts which they contain. Analysis is the only sure means of showing their exact composition.

Mode of improvement. Peat swamps must first be drained, to carry off the water, which renders them soft and spongy; they will then become hard. Siliceous and aluminous earth may then be spread upon them; yard-manure and lime or ashes will also improve their properties by decomposing the vegetable matters. Some recommend paring the surface and burning it; then by scattering the ashes over the soil, all the acid properties will be neutralized. The peat itself makes an excellent compost manure for the uplands, and should be carried into the barn-yard and mixed with yard and stable manures.

Degree of fertility. Peat soils are, or can be made very fertile; the want of fertility is not owing to any deficiency of vegetable matter, but to their texture and to the want of this matter in a soluble state, so as to nourish plants. When this is converted into vegetable food and the texture improved by draining and mixture of other earths, they are the most profitable of all soils; especially is this the case in New England, where these lands are in too many cases suffered to lie waste. Our peat swamps are decidedly the most valuable of all our soils, because they contain food for the plants of a thousand generations; they ought rather to be called manures than soils.

Crops. " Peat soils," says Buel, "are best calculated for oats, potatoes, rye, turnips, carrots and Indian corn; clover, timothy, red-top and other grasses." If the swamps in the eastern part of Massachusetts were fitted for grass, they would become more profitable than any other lands which are cultivated.

6. *Alluvial soils.* These have already been described, p. 231. It is a remarkable fact, that according to the analysis of Prof. Hitchcock, the alluvial soils of New England, and of the West, contain less vegetable matter than most other soils. Their fertility, therefore, must depend upon the mineral ingredients being in a more finely divided state, and to their power of converting insoluble into soluble food; it is hence inferred, that these soils will be soonest exhausted, unless supplied with vegetable and animal matters.

7. *Loamy soils.* Loams occupy an intermediate place between clayey and sandy soils, and originate from a constant course of tillage, and the application of animal and vegetable manures, for a course of years. It is the desire of our farmers, to bring all their soil into the state of loams.

Properties. The properties of loams are well known; they are less tenacious than clay, and more so than sand, They are very friable, capable of sustaining drought or wetness and easily ploughed at almost every season of the year. They are the most desirable of all soils. The alluvial soils described in the last section answer to the loams, as the materials are fine and beautifully mingled together. They are divided by Sinclair into four sorts: 1. sandy; 2. gravelly; 3. clayey; and 4. peaty.

CHAPTER VI.

IMPROVEMENT OF THE SOIL.

The improvement of the soil is the great object of agricultural chemistry. From a knowledge of the rocks and the agencies which have been active in crumbling them into soil; from the physical and chemical character of soils, and, finally, from the analysis in this country, we learn what they generally need to insure fertility. By an extensive analysis it appears that the earths exist in our soils in sufficient quantities, with the exception perhaps of lime; that the vegetable matters, alkalies and salts, are consumed by a continual course of cropping, and must be constantly supplied. The *mode* of improvement, then, relates *principally* to the application of vegetable and animal matters, alkalies and saline compounds, which latter includes carbonate of lime.

The agents which we have considered in the first two chapters, such as heat, light, affinity and electricity, depend chiefly for their efficacy upon the character of the soil. Vegetable substances, for example, render a sandy soil more retentive of water, and of caloric, as well as more compact. They render a clayey soil less retentive of water, but warmer and more friable and permeable by the roots of plants.

Carbonate of lime has been found an earthy ingredient of nearly all rich soils; and as our soils are nearly destitute of it, they would generally be benefitted by its addition. Alkalies and saline compounds, such as potash, soda, ammonia, nitre, common salt, etc. are, as we have seen, necessary for the maturity of plants; and, as they are exhausted by tillage, they must be supplied, to keep up the fertility. There are other modes of improvement, which pertain to the processes of tillage, which are all important, and which constitute the principal features of the modern system of husbandry. We have already referred, p. 242, on the classification and description of soils, to several modes of amelioration. In this chapter we design to describe at length, these and other modes of improvement, and to explain the chemical and mechanical principles upon which the various methods are based.

The following topics may fairly include all that is important on this branch of the subject.

1. Improvement of the soil by adding earths not existing in it, or existing in too small quantities.

1. Improvement of the soil by draining and irrigation.
2. By fallow crops and turning in green crops.
3. By rotation or interchange of crops.
4. By root culture.
5. By manures.
6. By tillage.

As the subject of manures is one of very great importance to the farmer, and, as it is somewhat distinct from the other modes of improvement, it will, in connection with that of tillage, occupy a separate chapter.

In the discussion of the above topics, it will be necessary to repeat many principles already suggested. As an apology for this, we simply urge the great importance to the farmer of thoroughly understanding the application of these principles in all their connections and relations.

Sect. 1. *Improvement of the Soil by the Addition of Earths not existing in it, or existing in too small quantities.*

This mode of improvement was described generally in the chemical classification of soils. A few remarks only need be added here, particularly applicable to the soils of New England, and, with a few exceptions, to this country.

1. *Carbonate of lime.** It is hardly necessary to repeat

* There is no subject, respecting which there is a greater diversity of opinion, among practical farmers, than that of the application of lime. It is said by some, to burn up the vegetable matter; while it is

here, that most of our soils are nearly destitute of lime, although reposing on limestone rocks. We have no soils which are strictly *calcareous*, and hence this earth may be added without the least fear of injury, but with the certainty of ultimate and permanent benefit. The quantity need not be large; four or five per cent. and even less will essentially improve the *texture* of the soil, and supply the necessary *earthy ingredients*, and it is in these two respects that we are now speaking of it. Hence it should be applied, for these objects, in the form of *marl*, *shell* or *ground limestone*. Quick or slacked lime applied to the soil soon becomes converted, in part, into carbonate, and air-slacked lime is already partially carbonated; but the application of lime in this form is better suited to it as a *saline manure*. The effect of lime, as an earthy ingredient, is to render cold, stiff clay soils more friable and light; of course dryer and more easily heated by the rays of the sun. Upon sandy soils, the effect is just the reverse; and, in addition, it enables such soils to retain the manures placed upon them, and counteracts the electro-negative character which the silicic acid or silex imparts to them.

2. *Sand* or *gravel*. When a soil is too clayey or peaty, its *texture* may be improved by the addition of sand or gravel. Their effect upon such soils is similar to that of lime. The sand gives to the clay a better consistency, and renders the peat more compact. It is easy to understand how this is; but it has been a question of some difficulty to determine whether sand or coarse gravel is the better form in which to apply siliceous matter. This question is one of easy solution, provided all the circumstances are understood. If the soil is peaty, the fine gravel will produce a more immediate effect, and loam is better than gravel; but coarse gravel will be more durable, because it not only supplies the earthy in-

believed, by others, to add greatly to the fertility. When applied as a carbonate, no ill effects can be experienced. In its caustic state, it may prove injurious by forming with the vegetable matter an insoluble substance, which thus removes a part of the vegetable food.

gredients which influence the texture, but also the decomposable minerals, which are equally necessary for the growth of vegetables. Loam, or fine gravel, spread directly upon peat meadows, after they are drained, will render them fertile at once; provided that a small quantity of lime, ashes, or other alkaline substance is added, to correct the acidity, and dissolve the vegetable matter.

If the soil is clayey, coarse gravel will ultimately prove the most valuable, for the same reason as above, and loam or fine sand will produce a more immediate effect; hence, the decision of this question, and the practice, will be one way or the other, according to the object we have in view in making the improvement. If a *sufficient quantity* of loam could be added, it would undoubtedly be better than either sand or gravel.

3. *Clay*. Sandy, light, peaty and calcareous soils are often benefitted by the addition of clay. The mode of applying it (as derived from experience and confirmed by theory), is to spread it upon the soil in the fall or commencement of winter, that the frost may break it down, and render it fit to be intimately mingled with the soil, by the process of ploughing and harrowing in the spring. Chaptal recommends the practice of baking and then pulverizing, by which process it approaches nearer to sand in its physical properties.

The utility of clay in agriculture has long been acknowledged, but the manner in which it operates is yet a little doubtful. Some things, however, are well settled. It adds its adhesive and retentive properties to sandy and peaty soils, and furnishes one indispensable earthy ingredient; but its effects are not wholly accounted for by the texture which it imparts. We must resort to its composition. Now it has been found that some of our clays, especially the clay marls, contain small quantities of carbonate of lime. By adding one earth, therefore, we actually add two, both of which are especially important to soils of the above description; for, where there is too much sand or silica, both clay and carbonate of lime operate to equalize the electrical forces; both act as converters of vegetable fibre into vegetable food.

A specimen of common blue clay from Lowell, analyzed by Prof. Hitchcock, gave

Water and organic matter	4.0	Oxide of Manganese	0.56
Silica	61.52	Lime	0.56
Alumina	20.50	Magnesia	.44
Protoxide of iron	9.82	Sulphur and loss	3.22

It will be seen by this analysis, that there is a large quantity of *protoxide of iron*, and this explains further its influence. "Our common clays," says Dr. Dana, "contain more or less of sulphuret of iron. The conversion of this into the *persulphate* of iron, is the natural consequence of exposure; free sulphuric acid then results, which acts on any lime in the soil forming sulphate of lime, or gypsum." But the most important effect of the *protoxide* is that in passing into the *peroxide*, it tends to induce decay in the vegetable matters, which are in contact with it; hence clay acts upon a soil as an alkali, an alkaline earth, and a metallic oxide.

Finally, clay has the property of absorbing gaseous bodies, which are useful in vegetation. Liebig attributes to it the power of absorbing ammonia, from which plants derive their nitrogen. Daubeny regards this power in a soil, as an indispensable condition of fertility.

As sand will improve a clayey or peaty soil, and clay a sandy soil, it is matter of no little astonishment that New England farmers have not resorted more frequently to this mode of amelioration. In various parts of the country, sand hills, peat swamps and clay beds, are so situated often, that it would be the easiest thing in the word to transfer portions of the one to the other, to the mutual improvement of all. It sometimes happens, that a soil is reduced to an impalpaple powder when dry, and to a soft paste when wet, while the earthy and vegetable ingredients are in the right proportions to ensure fertility. Such a state of the soil results from a long course of tillage, and is due to the fact that the minerals are all decomposed by the action of growing plants, and, without decomposable minerals in the soil, no plants grown upon it will come to maturity. Such lands, therefore, require gravel, sand or loam, and as in the cases above mentioned, the latter has been found to produce the best effect, while theory at least would lead to the opinion that the former would be most durable.

The general theory relative to these modes of improvement is, first to improve the *texture* and consistency and equalize the electrical state of the soil, and secondly to furnish those decomposable minerals which plants must have in order to mature their seeds.

There is a limit, however, to these methods, while time and expense are required to carry out a system sufficiently rigorous to produce the highest effect; but if the farmer will have patience, coupled with perseverance, he may have the satisfaction of seeing his soils gradually but surely approaching to the best possible texture, and to the most favorable proportions of all the *mineral ingredients.*

Sect. 2. *Improvement of the Soil by Draining and Irrigation.*

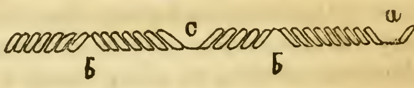
Wet soils originate from two causes. 1. When the water, which falls upon the surface, is retained by a retentive subsoil, as is often the case with level lands on clay bottoms. 2. When the water, which passes beneath the surface along the *water-bearing strata*, meets with *dikes*, or strata, which have been broken off, and incline in different directions. In the latter case, if the land is much inclined, there will be springs formed at the out-cropping of these strata, and, if the surface is level, the pressure of the water, from the surrounding high lands, will force it up to the surface, and produce a swamp, or too great a degree of moisture. In both cases the soil is rendered cold and unfruitful, hence fertility can be restored only by removing the cause of barrenness.

I. *Draining.* This mode of amendment can be applied only to stiff clays and swamps, or to lands which have a hard and retentive sub-soil, so that the water, in the ordinary course of things, will not pass off, and leave the land comparatively dry, for a considerable portion of the season.

The operations of draining are therefore confined to surface draining, draining the soil, and draining the sub-soil.

1. *Draining the surface.* In stiff clay soils, if the land is level or moderately inclined, the water from rains and snows is liable to remain on the surface, forming pools in every little hollow. This prevents the seeds, if sown, from sprouting, and injures the crop. When this water is evaporated, the surface becomes hard and impenetrable by air and heat, and by the roots of vegetables.

Fig. 14.



This evil is sometimes effectually remedied by simply throwing the land into ridges (Fig. 14) by a process called back furrowing, a process which every farmer knows well how to perform. It will be seen by inspection of this figure, that the water as it falls upon the crown of the ridge *b b* will pass off down both sides in the same way that it does when it falls upon the roof of a house, and either settle into the sub-soil, if porous, or into the furrows *a c* between the ridges.

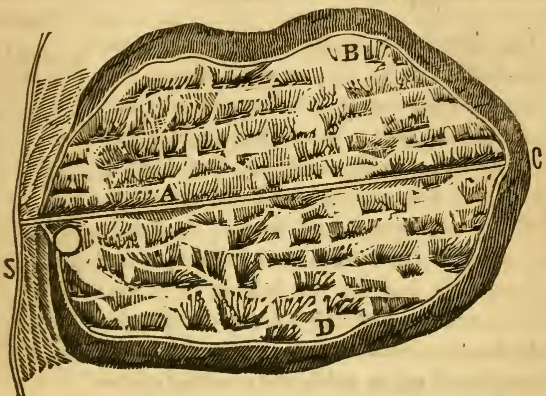
If the soil has an uneven surface and the water accumulates in the hollows, an *open drain* is the only effectual remedy.

But in cases where the surface is level and the sub-soil hard and retentive, resort must be had,

2. *To draining the soil.* This is effected by penetrating the sub-soil so as to form a passage for the water to pass off from the field, or a reservoir into which it may ooze from the soil.

The drains by which this is effected may be either *open* or *covered.* The latter, or underground drains, are the *cheapest*, most durable and most effectual ; for, aside from their convenience, a considerable quantity of land is saved for cultivation.

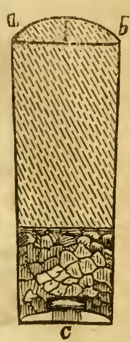
(Fig. 15.)



Before constructing a drain for this purpose, it is necessary to examine the land, and ascertain where the springs are. Most cases of surface-draining refer to swamps, or low lands. Suppose *B O D* (Fig. 15) is a swamp, or low ground in which the water collects, either from the high lands, or from springs in the margin *B D*, or anywhere in the centre of the meadow. The first thing to be done, in this case, is to make an outlet for conducting the water away to some stream as at *O S*. The second is to run a drain through the centre from *C* to *O*, and all around the margin *B D*, to cut off the springs, and to conduct the water into the main drain *A*, or outlet. In each case these drains should be sunk into the sub-soil, and if much water flow in them they should be open, especially the central drain. In this way the swamp can be rendered perfectly dry and capable of being cultivated.

Construction of under-ground drains. Under-ground drains should be from two to three feet in depth, in order that they may not be injured by the tread of cattle, and the heavy loads, which may pass over them. The sides should be a little flaring, that is, the drain should be a few inches wider at the top than at the bottom.

Fig. 16.



The materials used for filling up the lower portion of the drain, may be small stones, tiles or any hard substances. 1. If no water of consequence is to flow in them, they may be filled up, with these small stones, to the depth of from ten to fifteen inches, and the remainder filled up with gravel and loam. 2. But in case water is expected to flow in them, a *conduit* must be laid on the bottom (Fig. 16.) This is made by building a wall, on each side with stone or brick, about six or eight inches in height and six in width, and covering it over with flat stones so tight that mice or moles cannot get through it, and let in the soil from above and choak it up. If the earth is soft, the bottom also should be lined with stones. Upon the top of the flat stones, and upon the sides, fill in small stones *c* to the height of several inches according to the depth of the drain, and then cover the whole with earth *a b*, rounding the surface, so that when the whole settles, it may be even with the ground.

The conduit, in case stones cannot be found, may be made of tiles from clay, resembling earthen ware. These are laid together and form a complete tube for conducting away the water.

In some cases the surface may be drained by digging deep pits and filling them with stone. This mode is adopted when the sub-soil is hard or clayey, and a few inches below, are strata of sand or gravel. By digging through the retentive subsoil, the surface-water will run off.

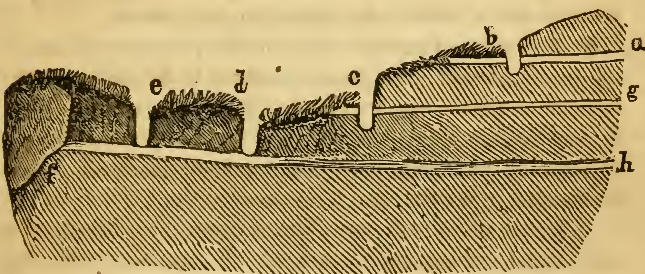
3. *Draining the sub-soil.* This process becomes necessary

in consequence of the inclination of the strata or layers of clay and rock near the surface. The sub-soil is often thus constituted, and these incline to the surface, or crop out upon the sides of hills. The water-bearing strata which lies below the sub-soil being brought to the surface, produce springs which are a fruitful source of wet soils.

The water in some cases rises up through the sub-soil by the force of pressure from the neighboring highlands, and produces a swamp.

In case of sub-soil draining, the object is to intercept the water below the surface by cutting through to the water-bearing stratum, and forming a conduit for it to pass off. This is the most difficult part of draining operations.

(Fig. 17.)



In order to show the nature of the difficulty, and the most common methods of remedying it, let us suppose that Fig. 17 is a section of a piece of land: *a* the high land, *d* a swamp, which may be produced by one or all of the water-bearing strata *a g h*, which crop out at *b c*, and produce wetness along the surface below. The water in *h*, meeting with the rock *f*, rises up at *e d*. The land from *b* to *c* may be drained by a ditch at *b*, conducting away the water at the point where it reaches the surface. The land between *c* and *d* may be drained by the ditch *c*. But as the water-bearing stratum h meets with resistance at f, open drains must be sunk at d and e, to conduct it off into some stream, in order to deprive the whole of superabundant water. It is not often that more than one water-bearing stratum crops out, and the most important point is to determine the cause of the wetness, in order to save time and expense in conducting it off.

Necessity of draining. The necessity and importance of draining wet grounds, may be rendered evident by the following considerations.

1. An excess of water or moisture prevents the ploughing and pulverizing of the soil until late in the season, and when the attempt is finally made, it can but imperfectly succeed; hence the manures, not being properly incorporated with the soil, are deprived of their effect upon the roots. The crop is checked and is liable to be injured by early frosts.

2. An excess of moisture prevents the process of decay, or the decomposition of the organic matters in the soil, and thus cuts off a *regular* supply of food. This effect is exemplified in peat-swamps, where the vegetable matters being prevented from decay by water, accumulate in large quantities, to the depth often of 20 feet, and form peat.

3. Lands which have an excess of water, often become *dry* and *compact* in seasons of drought. The roots are thus not only prevented from penetrating the soil and from extending themselves freely in all directions, but the influence of the air, and of the dew, which are so important in dry weather, are almost wholly excluded from them. Hence such soils, especially if they are stiff clays, suffer as much from drought as from excess of moisture.

4. When the roots of plants extend into a wet soil, the food is too much diluted, or is not prepared in sufficient quantities to ensure a healthful and vigorous growth. Leaves and ill-formed shoots will sometimes be abundant, instead of flowers and fruit. There are a few plants which will flourish

well in a wet soil, but not one in ten of those cultivated by the farmer. The following table shows the proportion of useless and useful plants on different soils. Whole number of plants are, in

Wet meadows	30,	useful 4,	useless 26.
Dry meadows	38,	" 8,	" 30.
Moist meadows	42,	" 17,	" 25.

5. An excess of water injures and destroys the fibrous portions of the roots, or spongelets, by means of which nourishment is received. This effect takes place always when the water becomes stagnant and putrescent, as it is liable to become, when the land is level and the sub-soil retentive. In some cases the tissue is decomposed, and the joints of the stem separated. In others, the plant rots off at the ground, especially if there is little light and heat.

6. An excess of water excludes the influence of heat and air, two indispensable agents to the growth of plants. De Condolle regards the influence of stagnant water about the neck of plants, as operating simply to exclude the oxygen of the air; but Lindley more properly attributes the injury to the *low temperature* of the soil, in which water is suffered to accumulate.

7. Experience shows that however well a soil may be constituted in its mineral ingredients, and however rich it may be in humus or geine and salts, no cultivated crop will flourish well unless the surface of the soil, and the soil itself is made dry during the growth of the crop, and when required to be worked by the plough or the hoe.

"It is because of the danger," says Lindley, "of allowing any accumulation of water about the roots of plants, that *drainage* is so very important. In very bibulous soils this contrivance is unnecessary; but in all those which are tenacious, or which, from their low situation, do not permit superfluous water to filter away freely, such a precaution is indispensable." Hence the

Utility of draining must be evident to every farmer. For a system of draining, rightly conducted, will not only remedy the evils above described, but will save much time and labor in the *cultivation* of the crop; two weeks, at least, will be gained in the getting in and ripening of it. The product will be one third greater, and one third of the labor saved in the tillage. "An outlay of 15 or 20 dollars per acre," says Judge Buel, "has often repaid, by extra product of the reclaimed land, in two or three seasons." In addition to these advantages, large portions of barren land, in many portions of the country, may, by this method, be reclaimed and rendered productive. We know, from actual observation, that some of the most valuable lands in Massachusetts, now lie entirely waste, in the form of peat-meadows and swamps, to the cultivation of which it is for the highest interest of every farmer to devote his immediate efforts.

II. *Irrigation.* Water, as we have seen p. 93, is essential to the growth of plants, both because it furnishes them food, and because it is the vehicle through which soluble matters are conveyed into the vegetable organs.

We know that plants will not flourish in a soil which is saturated with water; and we also know, on the other hand, that when the soil, without being chemically dry, contains so little moisture as to appear dry, vegetables will wither and die. The question to decide is, what amount is most congenial to the same species at different periods of their growth?

1. It may be taken as a general rule, that the proper time to water, is when the soil is deprived of moisture to such a depth, that the plants begin to languish and lose their leaves. The juices then become thickened, and the transpiration is nearly suspended; hence the plant will hasten to perfect its flowers and fruit, which will be incomplete and poor. The

effect of water, at such a period, is to dilute the sap and to furnish the means of transpiration; for all the excess of water, taken up by the roots, is thrown off by the leaves. Hence the quantity transpired depends upon that imbibed.

2. During the rest of plants in the winter of northern climates, and the dry season under the tropics, but a small quantity of water is required, because the plants do not transpire it. Excess of moisture at such seasons, often distends the vessels and exposes them to injury by the frosts of spring. No more water should be supplied than is taken up by the capillary attraction of the soil.

3. It is during the growth of plants, and when their leaves are fully matured, that the greatest quantity of water is required. The young leaf tranpsires much more in proportion to its surface than when fully matured, and hence requires a greater quantity to be absorbed by the roots; but when the leaves grow old, their cuticle hardens, and the apertures through which the water passes off, gradually become closed up; hence, water should be supplied to plants abundantly when they first begin to grow, and should be diminished as they grow older. During the ripening of the succulent fruit, plants require the least quantity; and if a large amount is supplied at that season, the fruit may be plumper, but will loose much in *quality*. Strawberries may be increased in size, by flooding their beds with water during the period of ripening, but they lose their flavor, and become insipid.

It will be perceived, that this mode of improvement is of limited extent unless in case of green houses and gardens. It is applicable chiefly to light sandy soils. Heavy argillaceous soils are never benefited by it. When dry soils are situated in the vicinity of streams or Artesian wells, water may be brought on to them with highly beneficial effects. The character of the water for irrigation upon dry lands, is a point of considerable importance. Water from a running stream is vastly superior to that from wells or springs, and the farther the water has run, before it reaches the place where it is taken on to the land, the more remarkable its effects. This is due to two causes; 1. It obtains a larger quantity of gaseous bodies such as oxygen and ammonia; and 2. it has been shown, that water from streams contains crenic and apocrenic acids often combined with silica, and also other salts, which it has dissolved out of the soil or rocks, as it has passed over them.

(1) The first effect of water, when made to flow over the soil by this process, is to soften it and render it more permeable to the roots of plants, and to the air.

(2) Water acts still further in dissolving out the food, and producing those chemical changes which must take place in the manures, before they are fitted for nourishment.

Care should be taken, not to apply water so often as to keep the soil in a state of paste, in which case, the plant may increase in size, but the products will be loose and spongy in texture, and vapid in taste. There is danger too, of favoring the growth of rushes and other wild grasses, which will take the place of the more valuable ones.

Another caution should be given on this subject, particularly applicable to garden plants; upon which surface-watering is sometimes practised during the dry season. The effect of thus pouring water around plants, especially in the heat of the day, is to render the soil compact and heavy; thus producing the very evil which it is intended to remedy. It excludes the air and the water which it contains from the roots. If surface-irrigation is ever practised on garden vegetables, it should be done at night.

Meadows seem to be most benefited by irrigation in our climate, although we know that in some countries as Egypt, it is practised upon all kinds of soil, and for every species of crop. In the vicinity of Liegen (Germany), according to Liebig, from three to five perfect crops of hay are annually produced upon the same meadow, by covering the fields with river water in the spring. "This is found to be of such advantage, that supposing a meadow, not so treated, to yield 1,000 lbs of hay, then from one thus *watered*, 4,500 lbs are produced," an increase of more than 400 per cent.

The practice of inundating meadows during the winter, is recommended both by Chaptal and Davy. The latter found that when the thermometer stood at 29° F. above the ice, it was 43° below it; hence, the roots of grasses are kept from freezing, and the whole plant remains in a green and vigorous state during the cold season. This practice, in this country, is too much confined to peat meadows, where the object is not to defend the herbage, but to prevent the frost from rendering the peat light and spongy.

SECT. 3. *Improvement of the Soil by Fallow Crops, and by turning in Green Crops.*

I. *Fallow crops.* "The fallow time," says Liebig, "is that period of culture during which land is exposed to a progressive disintegration by means of the influence of the atmosphere, for the purpose of rendering a certain quantity of alkalies capable of being appropriated by plants."

By "fallow crops" is meant the raising of some crop on green-sward while the turf is decaying, instead of allowing the land to remain a *naked fallow* during this process.

The object then of fallows, is to procure the decay of vegetable matters, and the abstraction of alkalies from the mineral portions of the soil.

Naked fallows accomplish both of these objects, and have been long practised both in this country and in England. The practice with us has been to plough up grass lands in June or July, and after cross-ploughing and harrowing, to sow with winter grain in September or October. In England, the land was formerly ploughed in the fall, and worked over during the following summer. In both cases one crop is lost; but, though naked fallows answer the intended purpose tolerably well, they are now abandoned by every intelligent farmer on both sides of the water; with the exception perhaps of wet stiff clays, which are ameliorated by exposing the naked furrows to the frosts of winter. The evils of the system are more than equivalent to the benefits. The labor is much increased, one crop is lost, and the vegetable matters are dissipated, by their exposure to the air during the process of working the land.

Fallow crops, on the other hand, avoid these evils, and secure greater benefit both to the soil and the crop.

Process. To prepare the soil for a fallow crop, all that is needed is to plough the green-sward and roll it down; then, after harrowing thoroughly, the seed should be sown upon the inverted furrows, either in the spring or fall. If the land is stiff and wet, the autumn is preferable; if light and dry, the spring is the best season.

The *utility* of fallow crops, instead of naked fallows, may be shown by reference to the influence of growing vegetables upon the soil. The elimination of alkalies and decay of vegetable matter are, as we have said, the only objects of fallows.

It may easily be shown, that both of these ends are much better attained by *tilling* the *fallow land;* for,

1. The alkalies are furnished in greater abundance by this process. It matters not whether the land is covered by woods, or with some crop which will take up but few alkalies, such as potash and phosphates. Now it is found that several *leguminous plants* will grow upon a soil, and will abstract from it but a minute portion of alkalies. The "Windsor bean (*vicia faba*) contains no free alkalies, and only one per cent. of the phosphates of lime and magnesia." (*Einhof.*) "The kidney bean (*phaseolus vulgaris*) contains only traces of salts." (*Braconnot.*) "The stem of lucern (*medicago sativa*) contains only 0.83 per cent., that of the lentil (*ervum lens*) only 0.57 of phosphate of lime with albumen." (*Crome.*)

"Buckwheat, dried in the sun, yields only 0.681 per cent. of ashes, of which 0.09 parts are soluble salts" (*Liebig*); hence, these plants with others, have been called fallow crops. It will be perceived, that the alkalies which the oxygen and carbonic acid of the air are eliminating from the soil, will be increased in this case, because the roots of the crop will permit these agents to act with greater power.

The *power of growing plants* to decompose the rocks, and to eliminate alkalies, has already been frequently referred to; and as but a small quantity of alkali is removed by the fallow crop, the amount in the soil is, upon the whole, increased.

2. It is further evident, that the roots leave in the soil *nearly* as much vegetable matter, as is carried away in the stalks and grain. This deficiency is made up by the influence of growing plants upon the humus of the soil. There is little doubt, but that decay proceeds much more rapidly when the soil is tilled, than when it is not; and the reason is, the galvanic agency of the roots and the facility which they offer for the introduction of air and water by loosening the soil, tend powerfully to hasten the decay of humus, or to convert the vegetable matters into vegetable food. The fermentation of the sod will be more complete when it is turned in deep, and the gaseous products will be retained by the superincumbent earth; hence we may draw an argument for deep ploughing, and for letting the sod remain until it has completely passed through the fermenting process.

II. *Turning in green crops.* The turning in of green crops, has long been a reputed source of rendering barren soils fertile. It is well suited to any soil which requires either to be rendered lighter, or to be filled with vegetable matter and salts. Light sandy soils, such as pine-barrens and loams, which have been exhausted by a long course of cropping without manuring, are most benefited, while stiff clays are rendered much warmer, and more friable.

Processes. 1. Green crops may be sown for the purpose and turned in, either before the seed ripens (in which case two crops may be turned in the same season), or after the crop is nearly ripe. In the first case, before the ripening of the seed, the plant derives most of its substance from the atmosphere; but when the seeds are maturing, it draws directly upon the matters in the soil. Some experiments have been made to decide which course is best, and they incline to the dry crop. If but one crop is to be added to the soil, this would be the best process, because it adds a greater amount of salts and humus; but two green crops are better than one dry crop. Buckwheat and oats answer well for this purpose. 2. But the better course is to save the crop by sowing clover with other grain, and the next spring turn it in; and, having rolled it down, plant directly upon the furrows with potatoes and corn. The surface, then, should be tilled with the cultivator or hoe, so as not to disturb the sod. Some recommend, in this case, to spread a light covering of compost-manure, lest the soil should be too much exhausted by the crop.

Now it is found that the quantity of vegetable matters added to the soil by this process, will exceed 12 tons to the acre. Elias Phinney, Esq. of Lexington, has actually weighed the vegetable matter in a cubic foot of *green sod*, from which he made an estimate that one acre contained more than 13 tons!

The best *time* for turning in green crops, or breaking up green-sward (unless the soil is a stiff clay), is the spring and early part of summer; because the *sod* will become rotted before winter, and will not afford, as it otherwise might, a shelter for worms, during that season, ready to injure the succeeding crop.

Theory. The theory of this process is exceedingly simple. It is evident that what is taken from the soil must be returned to it, or the land will be impoverished. We have seen that salts and geine are removed. This process simply restores them.

1. The green crop being buried deeply in the ground, soon begins to ferment and decay; a large quantity of organic food is thus added to the soil. But humus or geine is not the only substance required by plants. They must have alkalies.

2. These are supplied in part by the influence of the atmosphere, the ordinary process of disintegration. But this is trifling compared with

3. *The galvanic effect* of the living plant. The agency of growing plants has hitherto been overlooked in this connection. As the roots form a galvanic battery with the soil, they become the most powerful decomposing agents. Now we know that the poorest soils (the pine-barrens) contain a large quantity of alkalies, potash, lime, etc. locked up in the rocks. These are drawn into the organs of plants, where, as soon as covered with earth, they exist in a fit state to nourish future crops. If, then, we can make a plant grow *at all* upon such soils, we can render them fertile by turning in green crops, and thus furnishing the requisite amount of geine, alkalies and salts. If the soil is too barren to produce plants, a small coating of ashes will give a start to the green crop, and then the soil may soon be rendered fertile.

In case of clayey soils, the turning in of green crops not only restores what is exhausted by tillage, but renders the texture much better fitted for the roots of plants, and the soil itself a better retainer of heat.

In case of dry, gravelly soils, the additional vegetable matter gives the power of absorbing moisture and equalizing the heat; hence, it protects the plant from the extremes of dry and wet seasons.

The importance of this mode of improvement is not fully felt by our farmers. By sowing a few pounds of clover-seed with his grain-crops, the farmer may be constantly augmenting the fertility of his soil without the loss of a single crop; and even if his lands rest a year, and all their produce is given back to them, they will more than return it in a few years, by the larger *quantity* and better *quality* of their productions.

It will be seen that fallow crops and the turning in of green crops, are somewhat similar in their influence upon the soil. The object in both cases is to obtain alkalies or salts and geine. Fallow crops yield mostly the former, green crops principally the latter; and by both processes taken together, a soil may be rendered very fertile, without the addition of manures; especially for crops not requiring much nitrogen.

Sect. 4. *Rotation or Interchange of Crops.*

Rotation of crops is to cultivate, successively, on the same field, crops of different kinds and of different habits, such as common grains, roots and grasses.

The necessity and utility of an interchange of crops has been ascertained by experience.

1. It was found that the growth of annual plants was rendered imperfect, by cultivating them on the same soil in successive years; and that a greater quantity of grain would be obtained to let it rest for a season, during which time it seemed to regain its original fertility.

2. It was also observed that some plants, such as peas, flax and clover, do not thrive well on the same soil until after several years; whilst others, such as tobacco, rye, oats and Indian corn, may be cultivated in close succession.

3. It was further ascertained by experience, that one class of plants *improve* the soil, a second *impoverish* it, while a third class *exhaust* it.

4. To keep up the fertility, manure has always been employed. But however much a soil may be manured, it is

well established, that the produce of many plants diminishes, when cultivated for several years on the same soil.

5. But on the other hand, it is also fully settled, that when a field has become unfitted for one species of grain, it is not therefore unfitted for another; but that a succession of plants will flourish well without the addition of a large quantity of manure; hence has arisen the modern system of rotation. It now becomes a question of the first importance whether these facts can be so explained, as to aid us in pointing out the best system of rotation. If we can fully ascertain the causes of the failure of the successive cultivation of the same crop, and of the favorable effects of rotation, we shall be provided with the best hints for constructing a proper system. These causes are to be found in the structure of plants, in their composition, and in the influence of the matters which they excrete by their roots.

I. *The structure of plants*, such as their roots, stalks and leaves, afford one important reason for the rotation of crops. Each family of plants have similar roots, leaves, etc. Their action upon the soil is therefore similar. The spindle roots, for example, like the carrot and beet, extend their roots deeply into the soil, while the common grains lie near the surface. Clover and some of the grasses penetrate to a considerable depth, and branch out in all directions; hence, when one kind of crop is planted in the same soil for several successive years, the effect both mechanically and chemically is the same. Chaptal supposes that the roots exhaust only those portions of the soil which are in contact with them, and hence similar roots exhaust the soil in the same parts; but this effect could not take place when the land is ploughed between each crop, though it might apply to trees. This theory is wholly set aside by the fact, that the roots form a galvanic battery with the soil; and, as in all galvanic circles, the matter would be transferred from some distance around, so that the plant could stand in no need of food, provided it were surrounded by substances, which will keep up with it, the vigor of the galvanic action.

In addition to the mechanical effect upon the soil, we would suggest whether similar roots may not form with the soil similar galvanic circles of similar power and mode of action, and that the interchange of crops changes this action or restores its activity. We know that different metals require different substances to excite the voltaic currents, and that rest or a change of materials will restore the action of a battery, when its power is exhausted. *The reason why some plants exhaust the soil more than others*, is partly due to their structure. In this respect plants are divided into three classes.

1. *The culmiferous plants*, so called from *culm*, the stalk, which is usually hollow and jointed in order to afford support both to the leaves and seeds. Wheat, barley, oats, rye, Indian corn, tobacco, cotton, flax, hemp and the grasses, are of this class. All of them, save some of the grasses, are termed *exhausters* of the soil, and in all cases exhaust it more during the ripening of the seeds than during any other period of their growth. Flax and hemp are the most exhausting crops, because their leaves are small, and hence but a small quantity of their substance can be obtained from the atmosphere. They also return but a small quantity of matter to the soil, in the form of stubble and roots.

The smaller grains rank next in their power of exhausting the soil, because their leaves are narrow and roots small. They, however, return more to the soil in the form of stubble.

Indian corn, tobacco and rice, have larger leaves, and derive more of their substance from the atmosphere. The roots of culmiferous plants, being fibrous, do not penetrate and divide the soil so perfectly as those of the next family; and, on this account, do not leave the soil in so good a condition for succeeding crops.

Von Thaer has attempted to determine experimentally the different degrees in which different kinds of grain exhaust the soil. If wheat exhaust four degrees, rye will exhaust but three and a quarter degrees, barley but two and one fourth, and oats but one six-tenth degrees per bushel of the products.

2. *The leguminous plants*, such as peas, beans and other pulse, exhaust the soil much less than the preceding class, because their leaves are more numerous, and their stalks more vigorous. They are therefore able to derive more nourishment from the atmosphere, while their roots divide the soil more perfectly, and leave it in a better state for succeeding crops; hence they have been said to *impoverish* the soil.

3. *Root crops*, such as potatoes, turnips, beets, carrots, onions, cabbages and clover, exhaust the soil less than either of the preceding classes, and are hence called *ameliorating crops*. This class are provided with large fleshy and porous leaves, by means of which they obtain a large portion of their nourishment from the atmosphere, in the form of ammonia, carbonic acid and water. As these plants are seldom cultivated for their seeds, they rarely mature them the first season; hence they derive but little nutriment from the soil. Their bulbous or tap roots divide the soil more perfectly, and prepare it for succeeding crops.

The reason why some plants *foul* the soil more than others is also due to their structure. Plants which have small leaves, permit the weeds to grow, and to appropriate to themselves the nutriment which belongs to the crop. They also exhaust the soil most, while plants with broad leaves cover up and prevent the weeds from growing, and these also exhaust the soil the least.

II. *The composition of plants* explains the reason why some plants exhaust the soil more than others, and hence may aid us in forming a judicious system of rotation.

We have seen, p. 169, that different plants require different quantities and kinds of alkalies and salts, such as potash, soda, ammonia, magnesia, etc. to complete their growth; and when we examine their ashes, we find that some species require phosphate of magnesia or phosphates, and others potash, and others still, substances rich in nitrogen, such as nitre and ammonia. We have also seen that these substances exist in the soil, in small quantities, and hence are liable to be removed by a continued course of cropping.

1. If we take 100 parts of wheat straw they will yield 15.5 parts of ashes. The same quantity of barley straw will yield 8.54 parts, and 100 parts of oat straw only 4.42 parts. The ashes of all are of the same composition. The principal salts are *phosphates*, especially phosphate of magnesia, hence it is evident " that upon the same field, which will yield only one harvest of wheat, *two* crops of barley, and *three* of oats may be raised," and this is due to the different quantity of phosphates, which they derive from the soil, and if wheat succeed wheat, these substances will be sooner taken from it.

2. It is evident that if two plants grow beside each other or in succession on the same soil, they will injure each other if they withdraw the same alkalies from it; hence wild chamomile and Scotch broom impede the growth of corn, because they yield from 7 to 7.43 per cent. of ashes, which contain $\frac{6}{10}$ of carbonate of potash, the very alkali which the corn requires. If these plants succeed each other the same injury will be done.

3. But on the other hand if two plants grow beside each other or in succession, which require different quantities of any *alkali* for their development, they will flourish well; hence if a soil contain potash, wheat and tobacco may succeed each other although both are exhausting crops, that is, both require potash; yet they require different quantities of *phosphates;* thus for example, 10,000 parts of the leaves of tobacco-plant contain 16 parts of phosphate of lime, 8.8 parts silica, and no magnesia; whilst an equal quantity of wheat straw contains 47.3 parts, and the same quantity of the grain of wheat 99.45 parts of phosphates. (*De Saussure.*) Hence

the quantity of phosphates extracted from the soil by the same weights of wheat and tobacco must be as 97.7 to 16, and when the difference is so great as this, the plants may succeed each other.

4. Now if we examine what are called the ameliorating crops, we shall find that they contain a very small quantity of alkalies or of substances containing nitrogen, or of both. Thus the *leguminous* plants contain only traces of salts, p. 266, and hence they do not injure the crops of corn which are sowed with or succeed them. The root crops require still less of these alkalies and salts, and hence their ameliorating effects.

5. If we observe the rotation which is carried on in nature, for example, that pine trees succeed oaks, and oaks pines, and examine their ashes, we shall find the reason of it. "One thousand parts of the dry leaves of the oak yield 55 parts of ashes of which 24 parts consist of alkalies soluble in water," while the same quantity of pine leaves gives only 59 parts of ashes which contain 4.6 parts of soluble salts, (*De Saussure*); and generally those trees whose leaves are renewed annually, require from 6 to 10 times more alkalies than the fir-tree or pine.

6. It must be evident, without further examination, that the causes of the failure of crops when cultivated successively on the same field, and the reasons for rotation, are to be found in the kind and quantity of the substances, which each species of plant extracts from the soil. Some agricultural writers have held to the hypothesis, that each species of plant requires different kinds of food, and when it has exhausted *its specific* food from the soil, another species will flourish until *its* specific food is exhausted. We may learn from the above examination what this specific food is. It is the alkali* or salt which the plant requires for its development.

It should be remarked, however, that as one alkali may be

* See Liebig, p. 216.

substituted for another in some cases, we must seek still further for facts and principles, fully to explain the reasons for the rotation of crops, and their beneficial effect.

III. *The excretions which the roots of plants deposit in the soil* have been regarded by some as the most satisfactory mode of explaining the effect of cultivating the same crop in succession on the same field, and of the benefits of rotation. Liebig considers the view now to be presented, as the only one deserving "to be mentioned as resting on a firm basis." It is the theory of M. De Condolle, "who supposes that the roots of plants imbibe soluble matter of every kind from the soil, and thus necessarily absorb a number of substances which are not adapted to the purposes of nutrition, and must subsequently be expelled by the roots, and returned to the soil as excrements." Now as excrements cannot be assimilated by the plant which *ejected* them, the more of these matters the soil contains, the more unfertile must it be for plants of the same species. These excrementitious matters may, however, still be capable of assimilation by *another kind* of plants, which would thus remove them from the soil, and render it again fertile for the first. (*Liebig.*) In a word, one species of plants excretes by its roots substances, which are poisonous or innutritious to plants of the same family, but which may be assimilated by plants of a different species.

The experiments of *Macaire Princeps* prove, that the roots of plants do expel matters which cannot be converted into any of their component parts. Some of these excrements are of a gummy and resinous character, and are regarded as poisonous; others, are compounds of carbon and are nutritious. Liebig supposes that these excrements are not, according to De Condolle, derived from the soil, but from the atmosphere; and that it is in this way that a soil receives as much carbon from the plant as it yields to it. It now becomes an interesting inquiry what state this excrementitious matter is in, whether it is already fitted to nourish other species of plants, or must first pass through some chemical change?

It appears that the excrementitious matter of De Condolle is matter derived from the soil, and is not fitted to nourish that species, but may be indispensable to some other plant. It is undigested matter, and resembles the undigested excrements of animals, which, though unfitted to be assimilated by one animal, may prove nutritious to another.

The excrements of *Macaire Princeps* may be derived from the soil, but they are matters formed in the vegetable organs. They are compounds produced in consequence of the *transformations* of the food, and of the new forms which it assumes by entering into the composition of the vegetable organs. They are not, therefore, supposed capable of nourishing other species of vegetables, until a change is wrought upon them. This change is effected by the agency of the atmosphere, water, etc., and they are converted into humus.

These views do not contradict each other; both may be, and doubtless are true; both explain why it is that after wheat, wheat will not flourish so well on the same soil, and why one crop must succeed another to keep up the quantity of produce.

The latter theory, however, explains the fact that the excrements of some plants, affect the same species longer than others; for it is evident that the time required for the decay of the excrements may depend upon their nature, quantity, and the composition and character of the soil. In a calcareous soil it would be rapidly effected, and hence it is found that such soils admit of the same crop after the second year; or its decay may be effected by alkalies, and this is doubtless one of the good effects of adding these substances to the soil. But when the soil is siliceous or argillaceous, the same crop cannot be cultivated with advantage until the fourth or ninth year. Thus for example, "clover will not flourish in some soils oftener than once in six years, on other soils, once in twelve years. (*Liebig.*) The excrements of different plants require different periods to effect their conversion into humus; the excrements of flax, peas and clover, for example, when grown on argillaceous soils, require the longest period to effect this change.

From the views now presented, we may see the reason why the interchange of crops produces effects so highly beneficial. It is because the cultivation of different kinds of plants on the same field, enables each to extract certain components of the soil, which are necessary to it, and to leave behind or restore those which a second or third species may require for its growth, and perfect development. In constructing a system of rotation, therefore, we must have reference to the structure of plants, to the alkalies and salts which each species of plant requires, and to the matters which they excrete from their roots. We will therefore conclude this subject with a series of rules derived both from experience, and from the views now presented.

1. Two exhausting crops should not succeed each other on the same field, because their structure is similar, and they derive similar ingredients from the soil.

2. *Culmiferous*, *leguminous* and *root crops* should alternate with each other, because their structure, composition and excretions are most diverse, and the least injurious to each other. If the first crop is a hoed crop, the second should be a grain crop; although two hoed crops such as corn and potatoes, or turnips, are better than two grain crops.

3. A grain crop should succeed a hoed crop, rather than precede it. The reason in this case appears to be, that the manures can be more perfectly worked into the soil by a hoed crop, and the soil is left in a better condition for grain. There are, however, two exceptions to this rule. 1. When clover makes one crop in the rotation, it is found that wheat may succeed it with advantage, because they require different alkalies or salts, and the roots of the clover prepare the soil for

wheat better than most other crops; hence, it is the practice of the best farmers to cut their clover early, and turn over the sod for winter wheat. 2. A grain crop, as oats, may be taken as a fallow crop previous to wheat or rye.

The following will be found a good system of rotation. 1. The first year, beans, potatoes or Indian corn with manure. 2. The second year, wheat, rye, barley or oats, without manure. 3. The third year, roots, such as turnips, carrots or beets, with deep tillage and compost manure. 4. The fourth year, the same as the second year, with clover seed. The land should be smoothed and may remain in clover for a few years, or a clover crop may be taken, and a rotation, commencing with wheat and hoed crops, succeed in the same order.

In constructing a rotation system, however, the farmer should consult the demand for the articles which he raises, and the character of his soil, as a different system is required for dry and wet or stiff soils. He may select his crops at pleasure, provided he do not violate the principles already suggested. The old practice of growing the same crop for several years upon the same field, if adhered to, will certainly wear out his lands, and he will experience, what thousands have before him, the sure rewards of his folly, barrenness of his lands, and poverty of purse. It is astonishing that farmers have continued the practice so long. It would seem that their observations of what is constantly going forward in nature would have corrected the evil.

Forests are frequently alternating; hard wood succeeds pine; hemlock, pine and cedar succeed hard wood. Raspberries and strawberries are endowed by nature with roots by which they change their location. Natural meadows change their grasses gradually, and the fact is so general, that it may be regarded as a law of nature; change of plants being one of the means which nature employs to keep up fertility, or to restore her exhausted energies.

A good *rotation* system forms the basis of good husbandry. Without it, the soil may be kept fertile by the addition of great quantities of manure and rest, but with it, time and manure are economized, the soil rendered more and more fertile, and the products increasingly more valuable.

Rotation of fields. Rotation of fields is next in importance to a rotation of crops. By this we mean, that tillage, pasture and grass land, should alternate with each other. This practice is in opposition to the very common one, of devoting a certain portion of the farm perpetually to tillage; another to grass, and the remainder to pasture. Wherever it is practicable, these should alternate, and the same reasons may be urged as for a rotation of crops. Old pasture lands often become exceedingly fertile by the droppings of the cattle and may be cultivated with the best results, while tillage and grass lands are often benefited by turning them into pasture. In many parts of New England there are extensive swamps which may be cultivated, and made the most valuable lands. These lands are now either wholly waste, or used only as grass lands.

SECT. 5. *Root Culture.*

Root culture is not only an important means of improving the soil in a rotation system, but the products are the most valuable means of feeding and fattening cattle, and of producing manure. "It trebles" says Judge Buel, "the amount of cattle-food, and doubles the quantity of manure. It moreover may be made to supply a large amount of human food."

The principal roots suited to our climate, are the potato, turnip, carrot, beet, and those usually cultivated in our gardens. Of these the potato has come into general use. The beet, carrot and the Swedish turnip are the most profitable, both as to their influence upon the soil, and for the value of their products. The English turnip is very valuable for an after-crop, and tends to increase the fertility of the soil, especially if cattle and sheep are turned into the field, and allowed to feed upon them. This means of fertility, and of producing a large and valuable quantity of fall or after feed, is almost wholly neglected by our farmers. How easy it would be, after wheat or winter rye, to sow, say about the twenty-fifth of July, with turnips, and in October a good supply of feed would be furnished for the farm stock.

In the cultivation of root crops more attention must be paid to the character of the soil, and to its condition, than for the cultivation of grain crops, and hence it is that many farmers who have tried the beet and ruta baga have failed, by not attending to the proper conditions; but if the conditions are adhered to the crop is as certain, and much more profitable than grain crops. We will now proceed to point out the requisite conditions for root culture, with the theory of the action upon the soil. Attention must be paid to the following particulars.

1. *The soil.* This should not be too light and sandy, nor too stiff and clayey; a light deep loam or alluvial soil is best adapted to this crop. If the soil is wet, that is, if water is suffered to repose upon the sub-soil, the roots will be injured and the crop fail. The soil should be dry, but not subject to drought. *Depth* of soil is a necessary requisite for beets and ruta bagas in order that the roots may have full liberty to penetrate as far as needful for their perfection.

2. A *rich soil* is another requisite to success. This is desirable for all kinds of grain, but especially for root culture; for although roots do not draw upon soil, like grain crops, still there must be abundant food present, in order to give them that quality and perfection which makes them profitable crops. It may be that there is something in the constitution or vital powers of these plants, which renders a large quantity of nourishment necessary to their support. They may not possess the power of collecting food, like other plants; they cannot gather up the nutriment so readily, and

hence must be fed with richer food. The soil must be *finely* pulverized, and, so far as is practicable, freed from stones. This is necessary in order that the roots may not be obstructed; finally, they should be kept free of weeds. The ground should be stirred with the cultivator and hoe. If sowed in rows, as they should be, this may be easily attended to with the plough and cultivator, without the necessity of resorting to the hoe more than once in the season.

Theory of the action of roots upon the soil. 1. They divide it better than most crops; 2. they deepen the soil by their roots; and 3. return to the soil a larger amount of manure than other crops.

Three acres of grass, at two tons per acre, will give less than 9,000 lbs. to the cattle-yard, while one acre of ruta baga or beets, will give 36,000 lbs. or more than four times as much as the three acres of grass land. It would, therefore, be economy for the farmer to raise roots merely for manure. But the one acre of ruta baga or beets (600 bushels) are nearly equal to three acres of hay, as food for farm stock; hence the modes by which roots improve the soil, are dividing and deepening it, furnishing a larger supply of food, which enables the farmer to keep a larger farm stock, by which the quantity of manures are increased. Manure is the great source of fertility. In proportion, therefore, as root culture is made a part of a rotation system, we should expect the soils to increase in fertility.

CHAPTER VII.

IMPROVEMENT OF THE SOIL BY MANURES AND TILLAGE.

The improvement of the soil by manures surpasses all other methods. This subject is one that comes more directly under the notice of the farmer, than any other pertaining to his employment. It is one which may derive the most aid from science. In fact it is the most important branch of Agricultural Chemistry, to point out the best and cheapest modes of preparing manures in sufficient quantities; of applying them to different soils, and for different crops; and to explain the theories of their action both in the soil and in vegetation.

Manures contain all the elements of fertility. They are composed of decaying vegetable and animal matter (humus or geine), which constitutes the largest portion of them; of a small quantity of silicates, such as silicate of potash; and of salts, such as phosphates, nitrates, sulphates, carbonates and muriates.

Manures have been variously classified. A very ancient division is into animal, vegetable and mineral; thus indicating the source from which they are derived.

The classification proposed by Dr. Dana* appears to be the most scientific as well as practical. His classes depend upon the quantity of *geine*† and salts. This arrangement, with some modifications, will be adopted in this work.

1. Mixed manures, or those which consist of salts and geine.

2. Manures which consist mostly of salts, derived from animal and vegetable bodies.

3. Manures which consist mostly of geine.

4. Saline manures, or those which are composed of inorganic salts.

The points most worthy of attention, both in a scientific and practical view, are the nature and composition of the

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* Muck Manual, p. 124.

† The term *geine* is used here not as synonymous with *humic acid*, but with *humus;* and wherever it is used, in treating of this subject, it is intended to include the organic portions of *manures*, or the decaying organic matter.

different substances used for manure, their comparative value, the best methods of preparing, preserving and applying them, and the theory of their action in the soil. These topics, therefore, will receive particular attention in the following sections.

Sect. 1. *Mixed Manures, or those which consist of Salts and Geine.*

This class includes by far the greatest number of substances which are employed as manures. It includes, 1. the solid excrements of animals, such as those of the cow, horse, hog, sheep and fowls, night-soil and poudrette; 2. animal substances which contain nitrogen, such as flesh, fish, bones, hair, wool and soot; 3. animal and vegetable bodies, which are destitute of nitrogen, as oils, fats and spent lye of soap-boilers.

I. *Solid excrements of animals.* By an examination of several kinds of excrements, and their known effects, we can learn the reason of their influence; and, by comparison, ascertain what elements give them their comparative value.

1. *Cow dung* is taken, by Dana, as "the type of manures," or standard of value, with which all others may be compared. The following is Dana's analysis of 100 parts of fresh fallen cow dung.

	Water	83.60
Organic matter,	Hay	14.60
	Bile, and resinous and biliary matter	1.275
	Albumen	.175
Salts, . . .	Silica	.14
	Sulphate of potash	.05
	Geate of potash	.07
	Muriate of soda	.08
	Phosphate of lime	.23
	Sulphate of lime	.12
	Carbonate of lime	.12
	Loss	0.14
		100.000

Morin's analysis is very similar. Thus 100 parts consist of

Water	70.	Peculiar extractive matter	1.60
Vegetable fibre	24.08	Albumen	0.40
Green resin and fat acids	1.52	Biliary resin	1.80
Undecomposed biliary matt.	60		100.00

Others have given analyses varying somewhat from either of the above. In all cases there is from 70 to 85 per cent. of water, which of course is of no more value than any other water. By Dana's analysis a little less than one-sixth part consists of vegetable matter and salts. By other analyses, a little more than one-fourth is vegetable matter. A large portion of the vegetable matter is hay, bruised and deprived of a part of its gum and albumen. But by passing through the animal organs, the chopped hay has a greater tendency to decay than common hay. The living power has exerted a catalytic force, and the elements are disposed to separate; hence, nearly the whole soon becomes humus or geine. When subjected to ultimate analysis, 100 parts of cow dung are composed of the following organic elements.

Nitrogen	.506	Hydrogen	.824
Carbon	.204	Oxygen	4.818

The *absolute* value of this manure will not depend upon the quantity of these four substances, which it is capable of yielding to plants, but upon the quantity of geine, ammoniacal and other salts. The *relative* value will depend upon the proportion of nitrogen, or the quantity of ammonia which it is capable of forming. All manures may be estimated in a similar manner. This quantity of ammonia may be determined with some degree of accuracy from the known quantity of nitrogen ; for 14 parts of nitrogen and 3 of hydrogen combine to form 17 of ammonia. From these data, 100 lbs. of cow dung will yield 0.614 or about five-eighths of a pound of ammonia. This is generally combined with carbonic acid, and would make about 2 lbs. and 2 oz. of the *carbonate* of ammonia, which is known as *salts of hartshorn.*

The salts of potash, soda and lime, are much less. The whole, including the salts of ammonia, may be estimated at 2½ lbs. in 100 of manure.

The quantity of nitrogen in cow dung has been proved, by experiment, to exceed that found in the food eaten. A cow, fed on 24 lbs. of hay and 12 lbs. of potatoes, yielded daily 85.57 lbs. of dung, or 14½ lbs. of solid manure. This contained 3.03 of nitrogen, while the hay, etc. contained only 1.67 parts; hence, a part must be derived from the air.

The daily droppings of one cow are sufficient for one half bushel of corn. The quantity produced per year is sufficient to fertilize an acre. It will consist of the following substances.

Geine	4400 lbs.	Carbonate of lime	37 lbs.
Carb. ammonia	550 "	Common salt	24 "
Phosphate of lime	71 "	Sulphate of potash	15 "
Plaster	37 "	Total	31.025 "

Here is sufficient lime for 60 bushels of wheat, and the straw grown on 3 acres. But the power of the manure to form ammonia and nitrates, constitutes its relative value. The same is true of all other manures.

2. *Horse manure.* Recent horse dung is highly saturated with water, and covered with mucus. Its character and nutritive qualities vary somewhat, according to the nature of the food. Horses fed on grain yield, of course, a more valuable article, than those fed upon hay alone. According to the analysis of Dr. C. T. Jackson, 100 grains of recent manure consists of

Water	71.40	Carbonate of lime	.30
Veg. and animal mattter	27.00	Phosph. of magnesia & soda	.58
Silica	.64		
Phosphate of lime	.08		100.00

It will be seen that the quantity of vegetable and animal matter is considerably larger than in cow dung. It is as 14 to 27, or nearly double; and of course the quantity of nitrogen which it is capable of yielding is nearly double that of cow dung: 100 lbs. of fresh manure would yield about 3.24 lbs. of carbonate of ammonia and about .96 of phosphates.

3. *Sheep dung* is similar to horse dung, but contains a larger quantity of vegetable matter in a soluble state. It is also richer in salts; and the fact that it tends, like the dung of fowls, to putresence, shows that the quantity of nitrogen which it is capable of yielding, is greater than either of the preceding substances.

4. *Hog manure.* Hog manure is the most valuable of manures. It contains still larger quantities of soluble matter, and is capable of yielding a large quantity of nitrogen in the form of ammonia. We have not seen any analysis of hog dung, but from its known effects it ranks next in value to

5. *Night soil,* which has always been celebrated as the most valuable substance used for manure. The reason for its powerful effects may be learned from its composition: 100 parts of pure night soil contain

Water	75.3	Phosph. of lime and magnesia	.4
Animal and veg. matters	23.5		——
Carb., mur., & sulph. of soda	.8		100.0

It will be seen that the quantity of nitrogen, which night soil is capable of yielding, is about $3\frac{1}{4}$ per cent. The quantity of carbonate of ammonia, which may be formed by the nitrogen, is about 15 lbs. in 100 of night soil; hence, if its value is estimated by the ammonia which it is capable of forming, it is more than seven times that of cow dung. Experiments show, that if land without manure yields 3 for 1 sown, then by the addition of cow dung, it will yield 7 to 1; of horse dung, 10 to 1; and night soil, 14 to 1.

The substances now considered are generally formed together, and mingled in the cattle yard and hog stye. They constitute the great sources of fertility to the farm; and before describing the other substances, which come under this head, it is important to inquire after the best modes of saving and preparing them.

This knowledge may be obtained from the nature of the changes which take place in them, in passing to a state in which they can be absorbed by the roots of plants.

1. If these substances are exposed to the influence of rains, nearly the whole of the *soluble geine*,* the urine and soluble salts will be dissolved out, and washed away; hence, they should always be put under some kind of covering, such as a shed or barn cellar, which will prevent this waste. The practice of throwing manure from the stables into the open yard,† is as wasteful, as it would be for the manufacturer of soap or potash, to leave his ashes exposed to rains for a long time before leaching them. This evil may be corrected in part, by the shape of the

(1) *Cattle yard*, which should descend from all parts towards the centre; and by covering the bottom of the yard with swamp muck or peat earth, to absorb the juices which pass through. As a part of the manure is voided in the yard, such a shape is needed in order to secure it. About one third of the manure may be saved by these means. But,

(2) A *barn cellar* is the preferable mode of preventing this waste, because it is more convenient, and more perfectly secures the desired object. This should be of the same shape as the cattle yard, and lined in the same manner with muck. If now the hogs are permitted to work over the refuse of the stables, and the night-soil, a task which they will perform with admirable skill, provided a little corn is occasionally added, the leaching process will be entirely prevented, and the whole will be thoroughly mingled together.

* The term soluble geine, is used to include humic, crenic and apocrenic acids, and their soluble salts.

† Some recommend the practice of frequently sprinkling plaster over the manure and in stables, to absorb the gaseous ammonia, which will otherwise be lost.

2. If the manure is suffered to remain in the yard or cellar for any length of time, it should be covered with muck or earth, in order to absorb the gaseous bodies which will be evolved.

A series of chemical changes now commence. The whole grows warm, and after a few months crumbles down to a uniform mass, and becomes *short muck* or *rotted manure;* containing a larger quantity of soluble matter (soluble geine and salts) than it did in the green state. This process was formerly called *fermentation*, but now it includes the processes of *fermentation*, *putrefaction* and *decay*. The changes indicated by these terms, all agree in this particular; that new compounds are formed, either by a different arrangement of the elements which compose any one compound in the mass, or by the agency of air and water, whose elements combine with the ingredients of the manures. The matter, which has passed through the animal organs, is much more easily decomposed than it was before, and a series of chemical transformations commence.

(1) When bodies which contain no nitrogen are decomposed, the gaseous products have no odor; as when sugar is converted into alcohol and carbonic acid, and in most cases of fermenting liquors, the process is called *fermentation.*

(2) When bodies containing nitrogen suffer decomposition, and give rise to gases which emit a disagreeable smell, the process is called *putrefaction.* But these changes are of the same kind, although the latter is most beneficial to the farmer, as ammonia is generally formed.

(3) When any body decays at the expense of the oxygen of the air by a kind of slow combustion, it is called a process of *decay* ("*eremacausis*") and differs from fermentation and putrefaction in the circumstance, that oxygen is absorbed from the air *continually;* while in fermentation, if a small quantity of oxygen is admitted to the body, sufficient to commence the process, it will continue without further aid from

the air, and in putrefaction the air is not needed at all, but the process is often promoted by excluding oxygen altogether.

The carbon, oxygen, hydrogen, nitrogen and other substances of which manures are composed, form themselves into several new compounds which, without attempting to point out all the changes which take place, finally result in the formation of several bodies already considered.

These substances depend upon the conditions under which the changes take place. If the changes occur in the earth, they give rise to fossil coal. If they take place near the surface of the ground, or in the open air, which is the case under consideration, they give rise to the substances found in vegetable mould, p. 215, and in the atmosphere.

Theories of the changes which take place in fermenting dung-heaps, in the process of decomposition.

(1) *Carbonic acid* in large quantities is formed. This results either from the direct combination of the oxygen of the air and of water with the carbon of the plant, or from the union of the oxygen of the air with the hydrogen of the plant to form water, while the carbon and the oxygen of the vegetable is evolved in the form of carbonic acid. By this process, a large portion of the carbon is abstracted in a gaseous form, and unless alkalies or earths are present to absorb it, passes off into the atmosphere.

(2) Water is formed at the same time with carbonic acid. The hydrogen is furnished from the vegetable matter, and the oxygen from the air. The quantity of water thus annually formed in the soil, is probably greater than that which falls in rain on the same surface. In dung-heaps, the quantity of water formed is far greater than in the soil. In these products there is a genuine process of decay.

(3) As all parts of the heaps are not exposed alike to the action of the air, the hydrogen and the carbon combine and form carbureted hydrogen. The hydrogen is furnished either from the vegetable itself, or from the water which is known

to be decomposed in the process. This also escapes into the air.

(4) Sulphur and phosphorus are always constituents of manures, and combine with the hydrogen and form sulphureted and phosphoreted hydrogen; two gaseous bodies of very offensive odors, which escape in part into the air.

(5) The substances which contain nitrogen yield that element to hydrogen, and form *ammonia.* A part of this substance is absorbed by water and the vegetable matter, and a part is thrown off into the atmosphere; the remainder, which constitutes probably the largest portion, combines with carbonic acid, forming carbonate of ammonia, and with other acids, as the muriatic and nitric, which are formed during the process.

The above, with the exception of water, are the gaseous bodies given off in the process, and as the most valuable part of the manure is liable to be dissipated in this way, we have the best reason for covering the fermenting heap with a thick coating of earth or peaty matter.

(6) Nitric acid is usually formed in this process. Some have supposed that it results from the transformation of ammonia; others suppose that it may obtain its nitrogen directly from the plant, or from the atmosphere. The acid being formed, combines with the potash and forms *nitre* or saltpetre; and with other bases which may be present, such as soda, lime and ammonia.

(7) Sulphuric and hydrochloric acids are also formed; the latter acid deriving its chlorine from the salt which exists in animal excrements. It is probable that other acids are formed. All of them, however, are combined with bases in the form of salts. It is rare that any acid, excepting the carbonic, exists in a free state.

(8) The solid matters which remain, are found to consist in part of humic acid, humin, extract of humus, crenic and apocrenic acids. The acids are combined in some cases

with bases, and the whole taken together has been called geine and humus. But when the fermenting heap is exposed to the rains, the salts and the vegetable matters are dissolved by the water, and pass down into the soil or run to waste; hence, the reason for the direction above given, to place under the heap a thick bed of earth or swamp-muck, to absorb these liquid matters.

When these changes have proceeded awhile, the whole mass is converted into an effectual manure, into geine and salts, fitted for any soil or crop. If the heap contain a large quantity of animal matter, the tendency to putrefaction is much increased, a much larger quantity of ammonia is formed, and also a larger quantity of *nitrates*.

3. If the manures are carried, in their green state, directly upon the field, as a top dressing, the air of course, and not the crop, receives the larger portion of their valuable products. But if they are spread, and turned into the soil, the changes which we have described take place much more slowly, a circumstance which, on many accounts, is highly favorable to vegetation. The plant requires a constant and regular supply of nutriment, and this process supplies it. The heat, which always attends their decompositions, acts with great power, and with the best effect, especially in cold wet soils. The gaseous matters are directly absorbed by the loam, and more perfectly retained than they can be in the heap. Still it may be doubted, whether the manure, from its diffusion through the soil, is as favorably situated for those chemical changes, which must take place, before it can nourish plants. It may well be doubted whether so large a quantity of soluble geine and salts will be furnished in this way, as when placed under fitting circumstances in heaps, and whether more vegetable matter will not be dissipated in the air.

If, however, soils are wet and cold, manures should be applied in the green state, rather than permitted to ferment in the yard. It may be remarked, generally, that in all cases where manures are applied without forming them into *compost heaps*, they should be applied in the green state, but when composted with vegetable matter, it is far preferable to allow them to pass through the fermenting processes.

6. *Poudrette* is night soil mixed with ground peat and plaster, and dried so as to be rendered inodorous and portable. If the sulphate of lime and peat are added before it is dried, the ammonia will be converted into a sulphate, or absorbed by the peat and retained. The value of good poudrette depends upon the quantity of ammonia and geine. It has been valued in comparison with cow dung as 14 to 1.*

7. *Guano* is a very valuable manure. It is the excrements of birds, and is found in the greatest abundance on the islands of the Southern Ocean, where it forms beds from eighty to ninety feet in thickness. It is composed, according to Voelckel, of

Urate of ammonia	.9	Sulphate of soda	3.8
Oxalate of ammonia	10.6	Muriate of ammonia	4.2
Oxalate of lime	7.0	Phosphate of lime	14.3
Phosphate of ammonia	6.0	Clay and sand	4.7
Phos. of ammonia and mag.	2.6	Undetermined organ. sub.	32.3
Sulphate of potash	5.5	of which 12 per cent. is soluble.	

This substance is said to render fertile the soils of Peru, which do not contain a particle of organic matter. It will be seen from its composition that it contains all the elements of fertility, a large quantity of salts, and 12 per cent. of *sol-*

* There is yet another form of poudrette, which though much used in France, has not been introduced here. It is almost one-half animal matter, and it is formed without any offensive evolution of gas, by boiling the offal of the slaughter-house, by steam, into a thick soup, and then mixing the whole into a stiff paste, with sifted coal ashes, and drying. If putrefaction should have begun, the addition of ashes, sweetens the whole, and the prepared "animalized coal," as it is termed, or poudrette, is as sweet to the nose, as garden mould. It is transported in barrels from Paris to the interior, and is a capital manure.—*Dana's Muck Manual.*

uble organic matter. Liebig appeals to this example to prove that plants will grow without humus!

8. *Pigeon dung* and that from *domestic fowls* is similar to guano. The former has been proved by experiment to be $\frac{2}{7}$ stronger than horse dung. The manure of fowls has been applied with the best effects to peach trees, vines and other plants, which after a few years present the most luxuriant and healthy appearance. It may be applied by mixing one part of manure with 8 or 10 of water, and put around the roots.

II. *Animal bodies*, such as flesh, skin, gristle, sinews and bones, form by decomposition most powerful manures. They produce much larger quantities of ammonia than fermenting dung heaps, and are much richer in salts, containing in fact all the substances which are necessary to support the vegetable organs. The following table shows the composition of animal bodies.

Mineral Salts.	Sulphate and phosphate of lime, Phosphates of soda, magnesia and ammonia, Sulphate and muriate of potash and soda, Carbonates of potash, soda, lime and magnesia.	
Vegetable Salts.	Benzoate, Acetate, Oxalate,	Of potash, soda, lime.
Animal Salts.	Urate of ammonia, Lactate of ammonia.	

Oxides of iron, manganese and silica.

Animals and vegetables contain several substances, which appear to be identical. Gluten, vegetable fibrin, albumen and legumin, are vegetable principles, and the corresponding substances in animals are fibrin, albumen and casein. The last two are identical in composition with vegetable albumen and legumin. These principles are combined with alkalies, earths, sulphur and phosphoric acid. When deprived of their inorganic portions, they have been referred to a single organic principle, called *protein*, which is thus constituted.

Oxygen	21.288	Carbon	55.742
Hydrogen	6.827	Nitrogen	16.143
			100.

or in symbols $C^{48}H^{36}N^{6}O^{14}$. It appears now to be well established that this substance is the basis of animal bodies. *Fibrin* or *flesh*, and *albumen* or the white of eggs, are composed of protein and sulphur.

Horny matter is of two kinds, soft and compact. The *soft variety* includes the *cuticle* of the skin, and the lining membrane of the internal passages and sacs.

The *compact variety* includes horns, hoofs, nails, claws, scales, feathers, hair and wool. These substances all contain sulphur, lime, magnesia, and from ½ to 2 per cent. of bone earth.*

1. *Horns and hoofs.* The shavings and piths of horns and hoofs of neat-cattle make a very powerful manure. About 0.3 per cent. is phosphate of lime and earthy matter; the remaining substances are, in 100 parts,

Carbon	51.540	Nitrogen	17.284
Hydrogen	6.799	Oxygen and sulphur	24.397

The horns and piths may be cut with an axe or ground in a bone-mill, then mixed with green manure, a bushel to a load, spread upon the field, and buried with the plough. The fermentation of the dung promotes the decay of the animal matter, and large quantities of ammonia will be evolved.

2. *Nails and claws* are composed of

Carbon	51.019	Nitrogen	16.901
Hydrogen	6.824	Oxygen and sulphur	24.608

These of course will yield a large quantity of ammonia, and therefore they will constitute a powerful manure.

3. *Hair* is composed of

Carbon	50.652	Nitrogen	17.936
Hydrogen	6.769	Oxygen and sulphur	24.643

(*Scherer.*)

* Dana.

4. *Wool* contains, in 100 parts,

Carbon	50.653	Oxygen and sulphur	24.698
Hydrogen	7.029		
Nitrogen	17.710		100.000

5. *Feathers* are composed, in 100 parts, of

Carbon	52.427	Nitrogen	17.893
Hydrogen	7.213	Oxygen	22.467

Wool, woollen rags, and the refuse from woollen manufactories, hair and feathers, contain an oil in addition to their protein, which increases their value, and renders them excellent manures. The washings from the wool annually consumed in France, would yield sufficient manure for 370,000 acres of land. This wool-sweat is an excellent manure.

6. *Glue, jelly,* etc. is derived from cartilage, skin, bone and tendon, by boiling them in water ; but it is not found in healthy animals. It constitutes a powerful manure.

7. *Bones* are composed of animal matter, phosphate of lime and of magnesia, and carbonate of lime : 100 parts of the bones of the ox, as analyzed by Davy, yielded, of

Decomposable anim. matter	.51	Carbonate of lime	10.
Phosphate of lime	37.	Phosphate of magnesia	1.3

The value of bones depends upon their power of producing ammonia and salts. For the former purpose, they are at least 8 or 10 times as valuable as cow dung, and the quantity of salts is 66 times that contained in an equal quantity of that substance. They constitute, then, a most concentrated animal manure, and have been long used by the most intelligent farmers for improving their soils. For this purpose they are crushed in a mill, made for the purpose, and constitute *Bone dust.* The value of this manure may be estimated by the quantity which is imported into England, amounting annually to 800,000 dollars worth. It is estimated that this adds to the agricultural products more than 16 million bushels of grain. Bone dust is now used in this country to a considerable extent. One bushel to a load of yard manure, increases its value, as determined by experiment, one half.

Bone dust not only acts with great power, but its effects continue a long time; and, as it contains salts of lime, it is particularly useful to the soils of New England.

8. *Soot*, in its composition, is allied to animal solids, and may be described in this connection. It is a very valuable manure, as appears from its composition: 100 parts of soot contain, of

Vegetable matter	30.70	Acetate of potash	4.10
Extract. matter & nitrog.	20.00	Muriate of potash	.36
Carb. of lime and traces of magnesia	14.66	Acetate of ammonia	.20
Acetate of lime	5.65	Acetate of magnesia	.53
Sulphate of lime	5.00	Silex	.95
Phosph. of lime & of iron	1.50	Carbon	3.85
		Water	12.50
			100.00

If the value be determined by the quantity of salts and of nitrogen, in equal weights of soot and cow dung, the salts are as 20 in the former to 1 in the latter, and the ammonia as 40 to 1. The application of soot-water (6 quarts of soot to a hogshead of water) to green-house plants, has been attended with the best effects.

So valuable a substance ought to be saved with the utmost care, and either applied directly to the soil or to compost heaps. The latter use of soot is the most profitable, because it is capable of decomposing a large quantity of vegetable matter, as peat or swamp muck.

III. *Animal and vegetable substances destitute of nitrogen.* The only substances belonging to this class are oils and fats. In order to understand the action of these bodies as manures, it will be necessary to ascertain their constitution. Fatty bodies are acids combined with a peculiar base called *glycerine*, which is similar to stearine and margarine or fats, and to *oleine* or oils. The acids are stearic, margaric and oleic acids.

When oils and fats are exposed to the air, they yield great quantities of carbonic acid, and become converted into the above acids. The carbonic acid acts upon the silicates, and the organic acids act upon the alkalies in the soil, and form soaps, which, as salts, produce a most powerful effect in the processes of vegetation.

1. *Soap-boilers' spent lye.* In the process of soap-making, the alkali combines with the acid of stearine, margarine and oleine, forming stearates, margarates and oleates or soaps, while the glycerine remains in solution with the salts.

This latter substance is somewhat similar to geine, and is thus constituted.

Carbon	40.07	Hydrogen	8.92
Oxygen	51.00		

The oxygen, hydrogen and carbon exist in such proportions as to form water, carbon and carbureted hydrogen. It may yield to plants the same elements as humic acid. As about 8 per cent. of oils and fats is glycerine, it will readily be perceived, that the large quantity of this substance in spent lye, must render it a very valuable manure.

But this is not the only substance which gives to it its value. There are also various salts; the kind depending upon the alkali used to form the soap.

1. If potash is used (as it always is to form soft soaps), every 100 lbs. of soft soap requires about 8 bushels of ashes, and the spent lye contains, of

Sulphate of potash	6.5 lbs.	Silicate of potash	1.8 lbs.
Muriate of potash	0.3 "		

and a small quantity of potash in a free state. This adds greatly to the value of this article as a manure.

2. If now common salt is added to make the soap grain, or to convert the soft to hard soap, the salt is decomposed, the soda takes the place of the potash, and forms soda soap, while the chlorine combines with the potassium, forming the chloride of potassium (muriate of potash), which is added to the spent lye. The quantity will depend upon the quantity of salt* used.

* In a boil of 2,000 lbs. of soap, about 7 bushels of salt are usually added.

3. If the alkali is barilla or white ash, then the spent lye will contain, in addition to its glycerine, salts of soda; but as less common salt is added, in this case, the quantity of sulphate and muriate of soda will be less than the corresponding salts of potash. Ordinarily the spent lye of hard soap contains, per gallon, of

Sulphate of soda	6¾ oz.	Glycerine	½ lb.
Muriate of soda	½ lb.		

While that from hard soap contains, per gallon, of

Glycerine	½ lb.	Sulphate of potash	1⅓ lbs.
Muriate of potash (chloride of potassium)	5⅓ "	Silicate of potash	2½ oz.

It becomes an important question, whether so valuable a manure can be imitated by artificial methods. As soluble geine is similar to glycerine, the elements of spent lye from soda soap may be formed from swamp muck, ashes and common salt. Take 100 lbs. of peat, 1 bushel of salt, 2 bushels of ashes and 200 gallons of water. Mix the peat and ashes; moisten with water and add it to the salt in solution; stir it occasionally for a week, and it will be fit for use.*

Sect. 2. *Manure, consisting of Salts derived from Animal Bodies.*

This class of manures includes the *liquid* evacuations of animals, which are salts dissolved in water. These salts are different from those which will be described under the head of mineral or saline manures, because they are formed of an animal acid; that is, of an acid which is produced in the animal organs. This acid is found in urine, and is called *uric acid.* It is composed of

Carbon	36.11	Oxygen	28.19
Hydrogen	2.34	Nitrogen	33.36

The quantity of nitrogen renders it a powerful manure, as it becomes the food of plants. This acid appears to be de-

* Dana.

rived from an animal principle called *urea;* which may be obtained from urine in transparent, colorless crystals, very soluble in water, in which it suffers no change; but when mixed as in urine, it is converted into carbonate of ammonia. Alkalies produce the same effect.

Urea is composed of

Carbon	19.99	Hydrogen	6.66
Oxygen	26.66	Nitrogen	46.66

The oxygen, carbon, hydrogen and nitrogen are in such proportions, that they are converted *wholly* into carbonic acid and ammonia; hence, the quantity of *urea* in urine, is equal to its weight of carbonate of ammonia. The urea and uric acid, render the liquid excretions of animals equally valuable with the solid evacuations; and much more valuable, when vegetable matters are employed to absorb the gaseous products.

1. *Urine of the cow.* The liquid evacuations of the cow are composed of

Water	65	Sal amm. and mur. of potash	15
Urea	5	Sulphate of potash	6
Phosphate of lime	5	Carbonate of potash and amm.	4
			100

It will be seen, that the quantity of ammonia in the urea, as compared with cow-dung, is as 5 to 2; and in the other ammoniacal salts as 15 to 2, or about 4 times the quantity of the salts of ammonia in the liquid, that there is in the solid evacuations.

100 lbs. of this urine yield 35 lbs. of the most powerful salts; hence, the importance of saving the urine by introducing into the yard or barn cellar substances, as peat, which will prevent it from being washed away. If it is true, as has been shown by experiment, that a cord of loam saturated with urine is equal to a cord of the best rotted manure, and if one cow would furnish sufficient annually to manure an acre and one half of land, while the solid evacuations will not fertilize more than one acre, it must be evident to every far-

mer, that at least one half of his manure is wasted, if exposed to the influence of rains, and the ordinary action of the atmosphere.

2. *Urine of the horse.* The urine of the horse, and sometimes of other herbiferous animals, contains *hippuric acid*, which takes the place of the uric acid. The result, however, in vegetation is nearly the same, as the acid in both cases gives rise to ammonia by decomposition. The value of horse-urine will appear from its composition. 100 parts contain

Water	94.0	Carbonate of lime	1.1
Urea	.7	Hippurate of soda	2.4
Carbonate of soda	.9	Muriate of potash	.9
			100.00

From its composition, it is at least equal in value to cow-dung.

3. *Human urine* is equally valuable with either of the preceding. It is composed, in 1000 parts, of

Sal ammoniac	.459	Phosphate of lime	.209
Sulphate of potash	2.112	Acetate of soda	2.770
Muriate of potash	3.674	Urate of ammonia	.298
Common salt	5.069	Urea with coloring matter	23.640
Phosphate of soda	4.267	Water	967.511

The quantity of salts in 1000 lbs. of this urine is upwards of 42 lbs. The salts of ammonia makes it about equal in value to cow-dung, pound for pound; but as the other salts are more than double, 1000 lbs. of human urine is worth nearly 2000 lbs. of the best cow-dung.

If now we compare the quantity of salts in the solid, with these in the liquid evacuations, we shall find that human, horse and cow dung, contain upon an average, 1 per cent., while human urine contains 4.24 per cent., that from the horse 6, and that from the cow 35 per cent.

There is no substance, however, which varies more in composition than urine. Its composition depends upon the kind of food,* but it is always a most valuable manure. No farmer

* "White turnips give a weaker liquor than Swedish. Green

should permit it to run to waste, but should so prepare his cattle-yard by loam or swamp-muck, and by plaster, as to save these invaluable products of his stables, and of his own dwelling.

As the urine is generally mixed with the solid excrements in the barn-cellar or cattle-yard, it increases the value of this manure, it promotes its decay, and adds its own salts; but if the whole is exposed to the influence of atmospheric agents, it facilitates their action, and aids in depreciating its value; hence, it is generally wholly lost to the farm. Farmers ought generally to know this, and to be apprized of the fact, that one half at least of their manure is wasted. The preparation of liquid manures will be further noticed under composts.

Sect. 3. *Manures composed mostly of Geine.*

The refuse of the stables and of the farmer's dwelling, are the general sources of manure. But there are certain artificial preparations, which are equally efficacious, and which most farmers may employ to increase the fertility of their soils.

These sources are decaying vegetable matters, formed in various ways, into *composts*. The vegetable substances employed for these purposes, originate from two classes of plants, sea-weeds and land plants; and the manures which they form, differ in several important particulars, but agree in yielding all the elements of fertility.

In order to exhibit the facts and principles, connected with this species of manures in a practical light, it will be necessary to examine the composition of the substances employed

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grass is still worse. Distiller's grains are said to be better than either of these. Doubtless, the liquids of fattening kine is richer in ammonia during this period, for it contains a part of the nitrogen not carried away in the milk."—*Dana.*

for this purpose, and the changes which are wrought upon them, in their conversion into vegetable food.

I. *Sea-weed.* Sea weeds form a kind of manure which is much used along the sea board. The manure is formed from several species of plants, which are washed upon the shore by the waves and either carted directly upon the soil or used for litter and composted with other substances. The following are the principal varieties.

1. *Ribbon weed,* or narrow-leaved kelp, when green, is nearly four-fifths water. When dry, 400 grains, burned to ashes, yielded, of

Carbonate of soda (not weighed)		Silex	0.2
Phosphate of lime	3.3	Magnesia	3.5
Carbonate of lime	2.0		

"The vegetable matter of kelp is very gelatinous, and melts down during fermentation into a semi-liquid mass." The Scotch farmers make great use of this substance, and prefer laying it directly on to the soil, in its green state.

2. *~~Curagreen~~ moss* contains a gelatinous matter, similar to animal gelatine. It is used for food, and makes a delicate blanc-mange. Carrageen

3. *Rock weed* is highly gelatinous in its nature and very valuable as a manure.

4. *Eel grass* consists mostly of water and is much less valuable.

5. *Sea coral* is often thrown up with sea weeds, and adds greatly to their value. It is composed of the following substances: 100 parts contain, of

Animal matter	14	Phosphate of lime	1
Carbonate of lime	85		100

The quantity of salts contained in sea weeds renders them a very valuable manure.

Preparation and application of sea weeds. If sea weed is to be transported to some distance, it should be dried, to evaporate the water. It may then be spread directly upon the soil and ploughed in, or formed into compost with fish, or the refuse of the cattle yard. In either case it is an active manure; but its effects are not lasting, probably owing to the ease with which it is decomposed and either dissipated or absorbed by the roots of plants. It may be used for litter, to absorb the liquid and gaseous products of the stables, with the best results. Its value has been fully tested by many farmers who reside in the vicinity of the sea.

II. *Peat, swamp muck and pond mud.* These substances are very abundant in the eastern part of Massachusetts. Almost every farm throughout the country contains either peat, muck or mud in sufficient quantity for farming purposes.

1. *Peat* is derived from the decayed roots of sphagnous mosses, ferns, stalks of swamp-plants and decaying leaves; the peat moss constitutes the principal mass. There is also a small quantity of mineral matter, such as silex, clay, lime and magnesia, either mixed with it or combined with vegetable acids. Some varieties contain sulphate of lime (gypsum), oxide of iron and of manganese. The value of peat as a manure may be seen from its composition. The mean of 20 analyses of the peats of Rhode Island, by Dr. Jackson, gave the following results.

Water	from 10 to 25 pr ct.	Iron and alumina	1.34 per cent.
Ashes, when burned,	24.07 "	Lime	1.32 "
Vegetable matter	72.39 "	Magnesia	.32 "
Silica	4.31 "		

Four specimens contained a small quantity of potash, and one specimen contained 1.2 per cent. of phosphate of magnesia. It will be seen that peat contains a large quantity of vegetable matter and of salts.

2. *Swamp muck* consists of the pairings of the peat, and is less compact. It is found in every meadow, and includes the hassocks. It also includes the variety of peat which has become partially decomposed, and the mud of salt marshes.

3. *Pond mud* is found at the bottom of ponds, when dry,

and in low grounds. It consists of from 15 to 20 per cent. of vegetable matter, which has been washed down from the high lands and mixed with earthy materials. Dr. Dana has given the composition of 10 specimens of Massachusetts peat and swamp muck, dried at a temperature of 300° F. The average quantity of ingredients is 85 per cent. of vegetable matter; of which 29.46 is soluble and 55.03 is insoluble; 15.9 per cent. are salts and silicates. The composition of pond mud is very different, only 5 to 8 of insoluble and from 6 to 9 per cent. of soluble vegetable matter or geine. The salts of lime, however, are abundant, being about 2 per cent. It should be remarked that the proportion of the soluble to the insoluble portion is much greater in the mud than in the peat, and hence the effects of this substance will be more immediate, but not so lasting as peat and muck.

When peat is first dry, it contains from 78 to 98 per cent. of water. In drying, it shrinks two-thirds or three-fourths of its bulk. When green, it contains, of

Water	85.	Silicates	.5
Salts of lime	.5	Humus	14.0
			100.0

If, now, we estimate the value of fresh dry peat as compared with cow dung, we shall find that the two substances are constituted almost exactly alike. The salts and the geine or humus, in every cord of peat, are equal to those produced by the cow in three months. But there is one important difference. The cow dung is capable of producing a large quantity of ammonia, but the peat only contains slight traces of it. Still there is found crenic and apocrenic acids, which may serve the purpose of the ammonia, by yielding their nitrogen in the processes of vegetation.

The action of the ammonia, as we have remarked, is to induce decay and consequent conversion of the insoluble geine or humin into humic, crenic and apocrenic acids, or into soluble geine. If, now, there is any process of adding to the peat muck, either ammonia or any substance which will produce the same effect, we may convert it into cow dung, cord for cord. This may be done in the compost heap in the following ways.

1. *Compost of peat with alkalies.* The action of alkalies upon vegetable matter, to induce decay, has been frequently referred to. The action of all are alike in this respect; but the products are not all the same, and it becomes a question of great practical importance what alkali to use, and what quantity to employ, in order to produce the best effect with the least expense.

The alkalies employed to decompose the peat, and convert it into cow dung, are soda, ammonia and potash.

Ammonia is generally too expensive an article for this purpose. In other respects it would be the best, as all that would be needed would be to add about 2 lbs. of the carbonate or sulphate to every 100 lbs. of peat. As there are other alkalies in the peat, 1 lb. in practice has been found to answer the purpose. Potash and soda are almost the only alkalies which can be obtained in sufficient quantities, and at a price sufficiently moderate to answer the wants of agriculture.

In order to determine the relative quantities of the above-named substances, it will be necessary to resort to their equivalents; 1 part of ammonia is equal to 2 of soda, and 2 parts of soda to 3 of potash; or their equivalents are nearly as the numbers 1, 2, 3. But these alkalies are found in the state of salts; that is, combined generally with carbonic acid, carbonate of ammonia and soda or *white ash.* These are about equal in their effects, while pot and pearl ash, which are carbonates of potassa, produce but about two-thirds the effect. Hence, as cow dung contains 2 per cent. of ammonia, if we add to fresh dry peat 2 per cent. of carbonate of ammonia, 2 of soda ash, or 3 per cent. of potash, they will, in each case, convert it into that substance. By this estimate, as each cord, when dry, weighs 3216 lbs., it would require 84 lbs. of ammonia or soda ash, or 276 lbs. of potash. But when the peat is dry, it loses nearly three-fourths of its bulk; and hence would require about 736 lbs. of soda ash, or 1104 lbs. of potash. These proportions are found, by experiment, to effect the decomposition of the peat. But it is also found that a much less quantity of alkali will convert peat into cow dung. This is probably due to the fact, that not more than one-third of the ammonia contained in cow dung is active, and hence about 1 per cent. of potash will be sufficient for the compost heap. This will require for every cord of *fresh* peat 92 lbs. of potash, or 61 lbs. of soda ash, or 16 bushels of common ashes.

If these are composted together, a cord of the compost ought to produce effects precisely similar to cow dung. And experiments, so far as they have been made, seem to confirm the theoretical proportions. But a smaller quantity of alkali will render peat a very valuable manure; 20 lbs. of white ash, or 30 of potash to a cord, are found in practice to be as profitable as larger quantities. If spent ashes are used, 1 part of ashes to 3 of peat may be used.

Care should be taken to have the compost heap protected by a shed or a thatch of straw, and worked over two or three times before carrying it upon the land. In the process of fermentation which takes place, nitrates are formed and other salts of a highly salutary character.

There are other alkalies, which may be composted with peat, such as the spent lye of soap-manufacturers and lime. If spent ashes are used, a greater or less quantity of lime is also added. Some regard the lime which the ashes contain as less likely to render them beneficial in their effects. But if lime and common salt are both added to the peat, the lime will produce effects highly beneficial.

Take one bushel of salt dissolved in water, mix it with a cask of slacked lime, so as to make them into a thick paste, and let them remain for a week. This may then be mixed with three cords of peat, and shovelled over for about six weeks, and than applied to the soil.

Theory. The theory of the changes which are produced, may be known from the elements which are brought together. The salt is converted into soda and hydrochloric acid. When the lime is brought into play, the acid combines with it and forms a soluble salt; the soda acts upon the peat, evolves its ammonia as above, and becomes carbonated. Mutual decomposition of the carbonate of soda and muriate of lime now takes place, and carbonate of lime in minute portions is formed throughout the mass, ready to act upon the silicates and liberate their alkalies, and upon the geine, while the soda and muriatic acid are so combined as to form salt again. Composts of this description may be formed at an expense of not more than $2,25 per cord, and are believed to be very effectual manures.

A compost may be formed which will prove effectual, if the above does not. Add 61 lbs. of lime, and 61 lbs. of sal-ammoniac to three cords of peat, and an article will be formed, at an expense of less than $5,00 per cord, which will be fully equal in value to common yard manure.

2. *Composts of peat with animal matter.* Peat and swamp muck may be decomposed in a compost heap with refuse animal matter. " The carcass of a dead horse," says Lord Meadowbank, " which is suffered to pollute the air with its effluvia, has been happily employed in decomposing 20 tons of peat earth, and transforming it into the most valuable manure."

Urine will also decompose it by the action of its ammonia, and other salts; hence, the importance of having peat and swamp muck at hand, on to which the liquid excretions may be poured. In some countries, as in Flanders and in China, large tanks are provided into which the urine is conducted, and then either applied in the liquid state, or mixed with loam and peat earth. " Liquid manures," says Mr. Young, " are of the same value as the solid; one ton of solid dung will make four tons of compost, and four tons more may be made by the urine discharged by the cattle in the same time."

Night soil is similar in its effects. Fish also make an excellent compost, if lime is added to neutralize the acids or combine with the oils. Any refuse animal matter, such as woollen or cotton waste, and the washings of wool from woollen factories, may be mixed with peat and a most powerful manure formed.

3. *Compost of peat with green manures.* We have already described the process of preparing yard and stable manure; underlaying it, and covering it with loam or peat earth. The direct object in this case is to protect the manure, and save the valuable products of fermentation, putrefaction, etc. But in the process now to be described, the object is to decompose the peat, by means of the ammonia which green manures evolve. The quantity of ammonia in 100 lbs. of cow dung as we have seen, is about 2 lbs. This is sufficient to convert 200 lbs. of peat into a substance of equal value with cow dung. The urine which is mixed with stable manure will more than double this quantity; hence, if 3 cords of peat are mixed with one of stable manure, there will be formed 4 cords of manure equal in value to cow dung. These proportions agree with experience, and may serve to confirm us in the process, which has been recommended by practical farmers.

Process. In order to prepare a compost-heap with green manures, the peat should be dug and exposed to the rains for a while, to be deprived of its tannin and acids; then, when partly dry, it may be carried into the cattle-yard or shed, or on to the field, and mixed with green manure. A layer of peat should form the base of the heap, then a layer of manure, and then alternate layers of peat and manure, ending with a *thick* layer of peat. The shape should be conical, and covered, if exposed to rains, with a thatch of *straw*, or with boards. If lime or ashes are added, they will facilitate the process of decomposition. The heap, in the course of six weeks or two months, may be shovelled over and more peat added, if it is still in a state of fermentation. Some recommend the application of lime at the time of shovelling it over, in order to liberate the ammonia. It should then be carried directly upon the field.

The changes which take place are similar to those in fermenting dung-heaps. The result is the same, soluble and insoluble geine and salts. Lord Meadowbank, who first called attention to this subject, states "that in every diversity of soil, it has given returns, in nowise inferior to the best barnyard dung, applied in the same quantity, and that it is equal, if not preferable, in its effects for the first three years, and decidedly superior afterward."

The testimony of several New England farmers who have tried this compost, is that "three parts of peat with one of stable manure, make a compost which is equal in value to its bulk of clear stable-dung, and is more permanent in its effects."

It may be applied to any soil, either in the hill, or spread broad-cast and turned in; or it may be used as a top-dressing upon grass lands. In the absence of peat and swamp muck, composts may be formed with loam, straw, leaves, or any vegetable matter, which will absorb the gaseous and liquid products.

The quantity of peat and swamp muck in the eastern part of Massachusetts, is sufficient to render all her barren hills as fertile as the prairies of the West. The only difficulty there is in the case, is to persuade farmers to prepare it, and apply it to their soils.

Methods of applying manures. It has been a question of frequent discussion, whether manures should be applied to land in the green, or rotted state. The best answer to this question is, that they should not be applied in either state; but should always be made into composts, and applied after fermentation; and the reason is, that every cord of clear stable-dung may help form four of good rotted manure. But as farmers will continue to apply their manures in a pure state, a few rules may aid them to do it in the best manner.

1. For cold, stiff or wet soils, sheep and horse manure are the best, and should be applied in the green state, spread upon the land, and immediately turned under.

Theory. The reason is, that such soils require the heat incident upon fermentation of the manure. And, as it is diffused through the soil, the roots of plants feel its full influence. Such manures also render the soil lighter and dryer.

2. For light, sandy or gravelly soils, hog or cattle dung may also be applied in the green state, spread and ploughed in as above. Horse manure should be fermented, before being applied to such soils.

Theory. These soils do not require the heat, and a less quantity is produced in fermentation by cattle than by horse manure. By applying it in the green state, the gaseous products are saved, and one third of the manure; as it has been found by experiment, that one third at least, is wasted in passing to the state of short muck in cattle yards.

3. Green manures, however, should never be applied to any but a hoed crop. If wheat or rye are sown on lands manured at all, it should be rotted manure.

Theory. In a hoed crop, fermentation is most active in mid-summer, when the stalks and leaves need its influence; but in a grain crop, the kernel is *ripening* at that period, and fermentation is injurious to the process. If the straw is increased by the large quantity of carbonic acid which fermentation produces, the harvest will be hazarded; for the supply of food to the grain cannot be assimilated, and disease and consequent blight will ensue.

4. Rotted manure acts with greater power in the early part of the season than green; and hence, farmers generally

prefer it. But the green manure shows its superior effects in the harvest. The best rule is to apply to hoed crops a small quantity of rotted manure in the hill, to give the young plant a vigorous "start," but to spread the greater portion in a green state, to act upon the crop in mid-summer. The general practice of manuring in the hill is, by the best farmers, almost wholly discontinued.

Sect. 5. *Saline Manures, or those consisting of inorganic Salts.*

Mineral substances act as *manures*, when they enter into the composition of plants. They act as *amendments* or *correctors*, when they improve the texture or neutralize acids. They act as *solvents* or *converters*, when they induce changes in animal and vegetable bodies, or convert them into vegetable food. They act as *stimulants*, when they excite the living powers of plants by producing electrical changes, and other effects not well understood.

The substances, classed as mineral manures, are salts; that is, they consist of acids combined with alkalies, alkaline earths and metallic oxides. As fertility depends upon salts and geine, and, as the base of the salt, or alkaline portion, acts wholly upon geine, and in one uniform manner, p. 220, salts may be classed, with reference to the *peculiarity* of their influence, by their acids.

In this respect, salts may be divided into two classes. 1. Those salts whose acid nourishes plants; such are nitrates, carbonates and phosphates. 2. Those salts, whose acid poisons plants, or yields but a small quantity or no nutriment; such as sulphates, hydrochlorates or muriates.

I. *Salts whose acid contains the elements which nourish plants.* This class includes three families, which may be described as nitrates, phosphates and carbonates.

1. *Nitrates.* In this family of salts, nitric acid is combined with several bases. The three principal salts which

are used in agriculture are those of ammonia, potash and soda. *Nitrate of ammonia* is formed in fermenting dung heaps, but is rarely applied artificially.

Nitrate of potash, or nitre, is composed of 54 parts, by weight, of nitric acid (aquafortis) and 47 of potassa. This substance has long been a celebrated saline manure. Its effects are not only powerful but permanent. Upon what does its utility depend? In order to answer this inquiry, we have only to refer to principles already suggested.

Every 100 lbs. of nitre contain about 46 of potash. This acts only upon the vegetable matters of the soil, and is probably let loose from its combination, by growing plants (by catalysis). We have already noticed the influence of potash upon peat. 200 lbs. of nitre would furnish potash sufficient to decompose one cord of peat or muck. The action of the acid is more complicated. It contains 40 parts of oxygen and 14 of nitrogen. It may therefore be decomposed, and yield nitrogen and oxygen to the vegetable products, p. 164. But its oxygen probably acts both upon the vegetable matter and the silicates. By its action on the humus, a part is rendered soluble, and carbonic acid is formed, which acts upon the silicates, and liberates their alkalies. If the above is a true representation of the changes which take place, it proves that nitre is a most valuable substance to be applied to the soil. Experiment has shown that 100 or 150 lbs. of nitre, per acre, will produce the most gratifying results. It may be spread, or mixed with the manures.

Nitrate of soda is nitric acid combined with soda, in the proportion of 54 parts of the former to 31 of the latter. Its action is precisely similar to nitre. The soda acts upon vegetable matter, and the acid indirectly upon the silicates. The quantity applied may be about 100 or 150 lbs. to the acre, spread broad-cast, or mixed with the manures.

The above substances, including nitrate of ammonia, are the food of vegetables, and hence are properly classed as manures. There is, moreover, no danger of adding them in too large quantities. They are *nourishers*, and their action, as salts, does not produce insoluble compounds, but tends to render inert bodies active and useful. The nitrates are all exceedingly mild, although very active, and useful in their influence upon vegetation.

2. *Phosphates.* This family includes substances already considered, such as bone, earth, horn, hair, hoofs, etc. The only mineral phosphates, which may be used as manures, are phosphate of lime (apatite) and phosphate of magnesia; but these substances are not found in sufficient quantities to render their application practicable. Phosphates act very much like nitrates, the acid is food, and exists in vegetables in combination with magnesia. It also acts upon silicates, and eliminates their alkali.

Bone dust is principally phosphate of lime, and is a highly concentrated manure.

3. *Carbonates.* This family includes common limestone, marl and air-slacked lime; potash, ashes and white-ash or barilla. *Carbonate of lime* is known under the names of chalk, shells, marble, marl, limestone, etc. The most common forms in which it is used in agriculture, are shells, marl and air-slacked lime; although ground limestone has sometimes been applied to fertilize the soil. Salts of lime have long been used for agricultural purposes. Their beneficial effects were known to the ancients. They have been used in England, France and Germany for the last 100 years, with the very best results, and yet practical farmers are not all agreed whether lime is useful or hurtful in its effects. Experience shows that it is sometimes injurious and at others highly beneficial. Any theory, therefore, which shall enable us to decide the quantity which may be safely used (for it appears that the bad or good effects depend mostly upon the quantity employed), must be of the highest benefit to the practical farmer.

Theory. Carbonate of lime acts like all saline compounds; the base is let loose, by the action of the living plant, and acts in its caustic state upon insoluble vegetable matter, and converts it into vegetable food. The carbonic acid acts upon the silicates and obtains the potash and soda, which react upon the humus, and render larger portions of it soluble. The action is slow, but the effects are sure.

When lime is applied in a caustic state, it slowly absorbs carbonic acid, and becomes a carbonate. If a large quantity is used it may form a super-salt with humic acid, and become inert because insoluble. It is in this way that it proves injurious. But this state cannot always last, for the salt will, in time, be decomposed and rendered useful.

When acids exist in the soil, both the caustic and carbonate of lime tend to neutralize their effects; hence it appears that the base of lime acts in a four-fold capacity, as a *converter*, a *neutralizer*, a *decomposer*, and a *retainer*.

(1) Lime acts as a *converter*, when it converts vegetable fibre into vegetable food. This appears to be the most important use of lime, and the most difficult to explain. It has been referred to its "catalytic" power or to the action of presence, but whatever may be the nature of the force, it is well established, that when lime is brought into contact with vegetable matter, it hastens its decay. The humic or geic acid thus formed combines with it, and becomes a soluble salt, ready to enter the vegetable organs.

(2) Lime acts as a *neutralizer*, whenever acids exist in the soil in a free state. Some soils are called acid soils, and, as the carbonic acid is displaced by most other acids, the lime will combine with the acid and neutralize its effects. Peat and smamp muck often contain acids, which may be neutralized in this way; hence lime should be applied to peat earth, before it is used.

(3) Lime acts as a *decomposer*, when it decomposes any inert or injurious substance in the soil, as metallic salts. Veg-

etable matter forms, with alumina, a substance which is perfectly inert and useless (humate or geate of alumina). Lime will decompose it, and form a soluble salt (humate or geate of lime).

Sulphate of iron, or copperas, exists also in many soils, and is highly poisonous in its influence; lime will decompose this salt, and form sulphate of lime, or plaster, an effective manure.

As lime soon becomes carbonated in the soil, if applied in a caustic state, its action is nearly the same as when applied as marl or ground carbonate. In both cases, the acid acts upon the silicates, and decomposes them, hence lime will decompose the silicate of potash in spent ashes, and render the the alkali active.

(4) Lime acts as a *retainer* when it forms super-salts with humic, crenic and apocrenic acids. It thus locks up the vegetable matters, which it has converted into food, and this is one reason of its injurious effects. Still the matter is retained and will in the end all be appropriated. This effect must take place whether the quantity is large or small; but if there is a small quantity of vegetable matter in the soil, a large quantity of lime should not be applied. We have here a solution of the mystery relative to the effects of lime.

If lime is added in large quantities, and in a caustic state, it induces decay of the humus, and the formation of carbonic acid. It combines with both of the products, and if the proportion of vegetable matter is small, it will form so large a quantity of it into super-salts, as to injure the crop; hence it may be concluded, 1. That lime is useless on soils destitute of vegetable matter, and that it will not render them capable of sustaining vegetation. 2. That lime is often injurious on soils containing but a small quantity of vegetable matter. 3. That lime is highly useful, when applied to soils containing a large proportion of humus. If therefore, lime is applied to soils, vegetable matter must also be added, to ensure its good effects.

The utility of lime in agriculture, when properly applied, is well established by experience. The quantity required is small, one per cent., and even twelve bushels to the acre, are valuable additions. " A quantity of lime," says Mr. Puvis, " which does not exceed the thousandth part of the tilled surface layer of the soil, a like proportion of drawn ashes, or a two-hundreth part, or even less of marl, are sufficient to modify the nature, change the products, and increase by one half, the crops of a soil destitute of the calcareous principle." Sir John Herschel found that minute portions of calcareous matter, " in some instances less than the millionth part of the whole compound, are sufficient to communicate sensible mechanical motions, and definite properties to the bodies with which they are mixed." As such effects seem to be electrical in their character, we may conclude that there is a fifth office of lime, to act as a *stimulant*, by developing electrical currents. Upon the whole, we should prefer potash to lime, but the latter is unquestionably beneficial in its action, and may be applied in small quantities, as a cask to an acre, without any fear of injury, and with the certainty of ultimate benefit.

Carbonate potash. Potash is a carbonate, that is, it consists of carbonic acid combined with potassa. The action of the potash has already been considered, p. 306. It is sometimes applied to the soil from 100 to 150 lbs. to the acre. But the form in which it is usually applied is that of

Ashes. The value of ashes depends upon the kind of wood from which they are derived. Those from hard wood are more valuable than those from soft.

One hundred parts of hard wood, such as dry oak, beach, birch, etc. yield 2.87 parts of ashes. One hundred parts of dry pine yields only 00.83 of ashes, while 100 parts of wheat straw affords 0.44 per cent. The ashes consists of two parts, soluble and insoluble portions.

One hundred parts of the soluble, from hard wood, are composed of

Carbonic acid	22.70	Potash and soda	67.96
Sulphuric acid	6.43		
Muriatic acid	1.82		99.86
Silex	.95		

It will be perceived that the salts are not all carbonates, although the greater proportion of them are. One hundred parts of the insoluble portions contain

Carbonic acid	35.80	Oxide of manganese	2.15
Phosphoric acid	3.40	Magnesia	3.55
Silex	4.25	Lime	35.80
Oxide of iron	.52		

Peat ashes contain carbonate, phosphate and sulphate of lime.

Ashes, then, are composed of salts and silicates; they contain potash, lime and soda, and their use depends upon the action of these alkalies, which render them an efficient manure. Ashes are excellent for grass lands. One bushel of ashes contains 5½ lbs. of potash, a quantity sufficient to decompose 200 lbs. of peat earth.

Leached ashes correspond to the insoluble portions, and part of the lime is added, one peck of lime to a bushel of ashes, to render the lye caustic by absorbing the carbonic acid. Spent ashes, however, generally contain about 50 lbs. of silicate of potash per cord, so that they act both by their alkali and by their lime. *Silicate of potash* depends for its action wholly upon being converted into the carbonate of potash, and hence may be classed with the carbonates.

When ashes are composted with peat, they form a cheap and valuable manure; but should not be applied to the soil in large quantities, unless vegetable matters are also added. Ashes applied to light, dry soils, always act beneficially. On wet soils, they sometimes introduce mosses.

Barilla or white ash, may be classed as a carbonate; its
has already been considered, p. 367. The latter may

be applied to the soil, 100 lbs. to the acre, with the most perfect confidence in its utility. The former contains carbonate of lime, about half of its weight, with carbonate of soda. The ashes from antharcite coal contain carbonate of lime, alumina and oxide of iron, and are useful saline manures. Ashes of all kinds are particularly useful on grass lands. Peat ashes contain so much gypsum that they generally act with greater power than those from wood.

II. *Salts whose acid does not enter into the composition of plants, and which is poisonous.* This division includes, 1. Sulphates, such as sulphate of lime, iron, potash and soda. 2. Muriates or chlorides, as common salt, chloride of calcium, and of potassum.

1. *Sulphate of lime*, or plaster, has long been used as a saline manure. It has been proved by experiment, that " a bushel of plaster per acre, or even the one four-hundreth part of one per cent. produces effects on alluvial land, which shows its good results, as far as the eye can reach." This effect can be explained : on the supposition that plants decompose the salt, and let loose the lime upon the geine ; the acid must act upon the silicates, and form sulphates of potash, of soda, and (if silicate of lime exist) of lime. In this way the plaster reproduces itself.

Plaster has been found in some plants. It is supposed by Liebig, to act chiefly by condensing ammonia, and retaining it for the wants of vegetation.

Sulphate of iron, or copperas, is not applied to any but a calcareous soil, and the result is the formation of gypsum, by the action of lime to decompose the copperas.

2. *Chlorides.* Common salt is beneficial upon some soils ; it acts by the soda which it contains. Thirty bushels to the acre, has produced good effects. It may be best employed for composts.

Spent lye from soap-works has already been considered.

In all cases, the action of salts depends upon the presence of life. A living plant introduced into the soil, causes all the chemical forces to strive together to supply the necessary conditions for the perfection of the vegetable productions.

Application of saline manures. The quantity of salts used on any soil, must be determined chiefly by experiment. The following are the conclusions of M. Lecoq, who published the result of his experiments in his Prize Essay, 1832.

" 1. Salts, so far as possible, should be used in powder.

2. If used in solution, they must be diluted with a large quantity of water.

3. Saline manures may be advantageously used on all soils.

4. They answer best on light and dry soils.

5. They produce good effects on wet meadows, but must be used in large quantities.

6. It is preferable to spread salts at two epochs, in order to increase their action.

7. Some soils, especially those where mineral springs exist, and those around volcanoes, are already charged with a sufficiency of saline matter.

8. In too large quantities, saline matters injure vegetation. In too small quantities, they have no action.

9. The proportions that give the best results, are from 150 to 300 lbs. to the acre.

10. One hundred and fifty pounds to the acre is the best proportion for grazing lands and meadows.

11. These proportions must be varied with the nature of the soil; and 150 to 250 lbs. per acre, is generally the best quantity for light soil, but may be increased to 300 lbs. on mowing lands, and even to 600 lbs. on wet meadows, where we may use double this amount without injury to vegetation.

12. These are the proportions for sea salt and muriate of lime; they should vary with the other salts.

13. Fishery salt is prefered, as it is cheaper.

14. Sulphate of soda may be used in quantities from 300 to 600 lbs. per acre.

15. Acetate of lime exercises but little action on plants in quantities below 300 lbs. to the acre, and above this amount is injurious.

16. Ammoniacal salts exert a very marked action on vegetation, and may be employed in the quantities of 150 lbs. of the sulphate, or 100 lbs. of the carbonate, per acre.

17. Sea salt, in certain cases, may replace gypsum in artificial meadows; 150 lbs. of salt being equal to 5000 of gypsum.

18. Nitrate of potash increases considerably the crop, when used in quantities of 150 to 200 lbs. per acre.

19. The best time for spreading the salts is when the young plants begin to put forth their leaves. At the epoch of germination they are more injurious than useful.

20. Salts do not favor the production of seed, unless associated with organic manures.

21. They retard the maturity of plants, and give more development to the foliage, thus opposing evaporation of the liquids which they contain.

22. Burning the soil may be regarded as belonging to the class of saline manures, since salts are formed with the organic matters that the soil contains, and exert a very marked influence on vegetation."

This last means of obtaining salts may be practised upon peat meadows, where there is a large quantity of peat. The surface may be pared with a plough made for the purpose, and the turf collected in heaps and burned. Then by spreading the ashes, the peat will be rapidly converted into vegetable food. This practice, however, should not be resorted to, unless there are acids in the peat, or a large quantity of land containing peat. The vegetable matter is more profitably employed for composts. Salts may be obtained generally at a cheaper rate, than to burn *manure* in order to obtain them.

In conclusion, we would impress it upon the mind of the New England farmer, that the preparation and proper application of *manures*, are the sources upon which he must mainly rely for success in his profession. If all other subjects are disregarded which are here discussed, let him not neglect this; for if this subject is properly attended to, the rest will follow in its train.

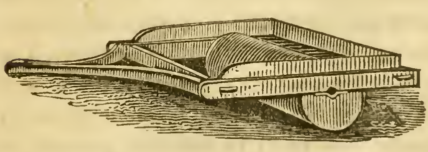
Sect. 6. *Improvement of the Soil by Tillage.*

By the term tillage, we mean those operations, which apply directly to the cultivation of farm crops. It includes the processes of ploughing, harrowing, rolling, hoeing and weeding. These processes belong to all kinds of tillage, whether intended to improve the soil, or to exhaust it.

We have already considered these operations in their relation to vegetation. In this section these processes are considered with reference to their influence upon the soil. But as the treatment is the same, whichever object is immediately to be pursued, only a few remarks need be added to those which have been made in the first chapter.

The great object of tillage is to render the soil light, to promote the circulation of air and water, a free extension of the roots of plants, to facilitate the chemical changes in the soil, and an equal distribution of the manures. The operations of ploughing, harrowing, hoeing, etc. have already been referred to, and our limits forbid any further remarks in this connection. These implements need no description.*

Fig. 18.

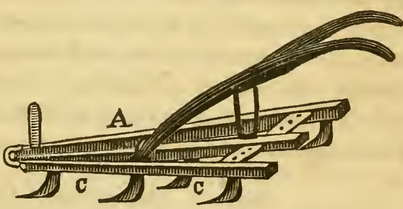


The utility of the roller (Fig. 14.) depends upon the fact that interstices or pores are left after plough-

* Ploughs are now manufactured by Nourse, Ruggles & Mason, Boston, which perform this part of tillage in a very superior manner.

ing, or the frosts of winter, which expose the roots of plants to injury. The roller breaks down the lumps, and gives compactness to the whole mass. The good effects of passing the roller over fields of winter grain or grass lands in the spring, have been fully tested by experience. The earth, which the frost has rendered porous, and which does not therefore embrace the roots, is rendered more com pact. On light sandy soils, the use of the roller is almost indispensable, by closing the pores and preventing the evaporation of the moisture, which such soils most require, although they are more liable than any other to yield it up.

Fig. 19.



The utility of the cultivator (A. Fig. 19), may also be referred to, as this implement may be employed to save the labor of hoeing. It also leaves the ground in a better state than the plough, when used among hoed crops. But it is not our purpose to describe the instruments of tillage.

We may observe, in conclusion, that thorough ploughing, harrowing, hoeing, weeding, etc. will incorporate the manures with the earthy ingredients, and promote, in the best manner, the influence of all those atmospherical and other agents which are required *to fit the soil to sustain a vigorous and healthy vegetation.* It is hardly necessary to add, that the ease of cultivation and the quantity and quality of productions, will depend, materially, upon the *faithful* and *seasonable* performance of this branch of the art of husbandry.

CHAPTER VIII.

PRACTICAL AGRICULTURE.

Under the head of *practical agriculture* we wish to include the modes of cultivating the farm crops; the character and value of each species of grass, grain and root, which are usually cultivated by our farmers. As these modes of culture are derived from experience, an opportunity will be afforded of testing the truth of many principles discussed in the preceding chapters. This subject, however, must be treated in a concise and general manner. We shall present the views of practical farmers, and attempt to show their consistency with scientific principles. Another topic under this head will be the relation of farm stock to the cultivated crops, a few suggestions upon which will close the chapter.

Sect. 1. *Cultivation of Grains.*

The following are the most important cultivated grains: Indian corn, oats, barley, rye and wheat.

I. *Indian corn*, or *zea mais*, is a native of this country, and was unknown to Europeans until after the discovery of America. In consequence of the different climates and soils in which it has been cultivated for a long series of years, there have been produced several varieties, differing more in appearance and habits than many distinct species of plants. We know how some of these varieties are produced, and this may instruct us in the selection of the seed, in order to improve any particular variety, or to obtain a new one. One mode of obtaining varieties of corn, is by selecting the seed. Thus, for example, a celebrated variety has been produced in the Southern and Western States, by selecting the first year the seed from stalks which bore two ears, and taking the top ear to plant. The second season there were some stalks of three ears; and the top ears from these were then taken and planted; and this process was continued for a series of years. The consequence was, that the stalk became very high; and the number of ears upon a stalk increased from one to five, and even eight. It should be remarked, that though this process gave a distinct variety, yet it would have been a much more valuable variety, in this case, if the lower ears had been taken; by which means the stalks would have been lower, the ears nearer the ground, and hence much less liable to injury, and more likely to be early, plump and well filled. By the selection of seed, also, an early or late variety may be obtained. Thus, for example, if those ears which ripen first, are selected from year to year for seed, in the course of eight or ten years an early variety may be obtained; and if those ears which ripen last are taken, under similar circumstances, a late variety may, in like manner, be obtained. Hence, in the selection of seed, the farmer should consider what variety he wishes to obtain. In the Eastern States, an early crop is desirable. In the Southern States a late crop. The number of rows on an ear depends upon similar treatment. Some prefer eight-rowed, others twelve or more. All these varieties may be produced by selection of seed and proper culture.

The seed corn should be selected in the autumn, before harvesting, and hung up by the husks. Before planting, it is a good practice to soak it for twenty-four hours in copperas-water or brine, as this will facilitate germination and prevent the wire-worm from eating it up.

Soil. The soil for Indian corn should be a light sandy or gravelly loam. A rich dry soil is always to be prefered. In heavy moist soils, it will not flourish as well as potatoes and most other hoed crops. It should be planted after grain crops or clover. Corn may be manured in the hill with compost or rotted manure. It is much better, however, to spread green manure or compost, and turn it into the soil.

The corn may then be planted in rows, about three feet apart, and from five to six kernels in a hill, lightly covered with loam. It is desirable in theory to spread fifteen or twenty loads of green manure to the acre, and turn it under, to act upon the crop late in the season, and then to put five or six loads of compost in the hill, to give it an early start; this corresponds with the experience of the best farmers.

The after culture consists in two or three hoeings, or one cleaning with the cultivator and two hoeings. The first hoeing should remove the earth from the roots; the second should raise it into the form of broad, flat hills. Some experiments, however, seem to prove that corn is best cultivated on a flat surface, with a tillage depth of from six to twelve inches; and theory would lead us to the same conclusion. The practice of making hills, injures the roots and exposes them to the influence of drought.

The modes of harvesting corn are various. Judge Buel, after repeated experiments, recommends the practice of cutting it up by the roots, and shocking it in the field, when the kernel has become glazed, so as to yield but little juice when broken open, and while the leaves are still green. We must confess that this practice has, upon the whole, more reasons in favor of it than any other.

It saves labor ; for the expense of cutting and securing an acre is not more than that of *topping* it.

It adds to the quantity of grain ; because, when the tops are removed, the nourishment which would go to the kernel is cut off; while, by letting the whole stand for a few days, and then cutting it up by the roots, the process of assimilation will continue to go on for three or four days afterward.

It increases the quantity of fodder and preserves its *nutritious properties ;* for it is not exposed so directly to the influence of the weather, and a larger quantity of the green parts is preserved. And, finally, it yields *more manure* and is secured against *early frosts;* for if it is cut when it is full in the milk, it will ripen in the shock.

The expense of this crop, and the value of its proceeds, may be estimated as follows.

Ploughing,	4,00	Produce, 35 bushels,	$35,00
Manure,	12,00	Corn fodder,	10,00
Furrowing,	,75		
Planting,	1,50		$45,00
First hoeing,	2,50		28,75
2d and 3d hoeing,	4,00		
Gathering,	2,00	Profit,	$16,25
Husking,	2,00		
	$28,75		

This, we think, is a very low estimate of the value of this crop; for the manure ought not, all of it, to be charged to the corn, as it generally suffices for two more crops. And although the average may not be more than 35 bushels to the acre, still 40, 50, 60 or even 120 bushels are often obtained in the Northern and Middle States, and in some cases 170 bushels in the South and West.

Broom-corn is cultivated to a considerable extent in the valley of the Connecticut river, and is a very profitable crop. The particular mode of its cultivation is not a matter of general interest. It is a crop which yields a great amount of matter; but as it rarely matures its seeds, it does not ordinarily exhaust the soil as much as Indian corn.

2. *Wheat* has been cultivated from the most remote antiquity. With us, two species are known, *winter wheat* (*triticum hybernum*) and *summer wheat* (*triticum æstivum*).

The grain itself appears under two varieties, the *flint* or *dark colored*, and the *white* or *thin-skinned.* Some varieties are bearded, and others are bald. The white soft-skinned varieties succeed best in dry soils and warm climates; the red and flint varieties prefer a moist soil, and a cool temperaature.

In selecting seed wheat, any variety may be improved; and it has been found that the *best method* is to go into the field when it is fully ripe, and select the *longest* and *fullest heads, from which seed wheat may be raised the following year.* If this course is pursued, the crops will constantly increase in value.

The quantity of seed per acre for winter wheat, may be one bushel and a half, if sowed in September so that the stalks may spread themselves. If sown in the spring, at least two bushels per acre should be employed.

The soil for wheat should be a deep loam, perfectly fine, dry and light; containing a good proportion of clay and carbonate of lime. It should be *thoroughly* and *deeply* pulverized.

Wheat should not be sown on green manure, but a clover ley, or a potato crop the previous year is the best preparation.

The depth at which it is sown should be two inches, unless the land is very finely pulverized; in which case it will flourish much better, if it is placed only one inch below the surface. The ground must be thoroughly drained, and if the sub-soil plough is used, it will very much increase the value of the crop. Wheat requires phosphates and substances rich in nitrogen. It will therefore be improved, by adding to the soil, salts of ammonia, lime, clay, saltpetre or bone manure.

There is nothing worthy of notice in the mode of harvesting this crop. It should be left standing until the grain is fully ripe and hard.

Diseases and enemies. Wheat is subject to disease, and to the attacks of insects, which are frequent causes of its failure, and which render it in many places an uncertain crop. The principal diseases are rust, smut, and mildew or blight.

1. *Rust* is a well known disorder, in which the straw becomes covered over with a *red powder* like iron rust. This stops the growth, and renders the grain shrivelled. Rust takes place either in a season of drought, or in July and Au-

gust, when the weather is damp and warm. The wheat is thus forced to such a rapid growth that the vessels are burst, and the sap exudes and causes the rust. In either case there is no known remedy.

2. *Mildew* or *blight* gives to the plant a purple or bluish cast, resembling the mould on damp walls; and is supposed to be due to a species of parasitic plant, a fungus which attaches itself to the stalk. This happens during warm, wet weather, or heavy dews. The only remedy is to brush off the water in the morning by dredging the field with a rope.

3. *Smut* is of two kinds. The first kind is seen in the heads, about the time of the ripening of the grain; the heads soon disappear, leaving nothing but the naked stalks. The second kind appears in the form of a black dust, which soon spreads itself over the field. The grain is not destroyed, but the flour is rendered black and poor. This is also supposed to be a species of fungus, as it can be propagated through a field. This disease may be prevented by soaking the seed in strong brine or stale urine, sprinkling it while wet with slacked lime, and leaving it for twenty-four hours before sowing.

The *enemies* of wheat are the *wire-worm*, *Hessian fly* and *grain insect*.

1. *Wire-worm.* This worm is well known to farmers, and its ravages are mostly confined to the sward. This effect may be remedied by ploughing in the fall, so that the frosts of winter may destroy the worm.

2. The *Hessian fly* is found as a maggot between the leaf and the culm, in the first joint of the plant, and, by bedding itself in the stalk, destroys it. No certain remedy, for the ravages of this insect, has as yet been found. Late sowing will sometimes carry the crop beyond the fly-season.

4. The *grain insect* appears in the form of a fly, hovering over the field about the time the grain is in blossom. It deposits its eggs, from which a yellow maggot is hatched, and appears in the head after it has destroyed the grain. A

complete preventive against this insect has been discovered, which consists simply in sprinkling, at the flowering season, slacked lime over the grain while wet. Mr. Colman thinks that this may generally be relied on as a certain preventive.

The barberry bush has been thought to be injurious to wheat, rye and barley, by causing it to blast.

Rye is the seed of *secale cereale*, and has also been long cultivated for food. In the north of Europe, it ranks next to wheat for bread, and is used, for the same purpose, in many parts of this country, particularly with Indian corn for brown bread, a very healthy and cheap article of diet. Rye is not regarded as a very profitable crop, but if we consider the fact, that it will grow on sandy plains, with little or no manure, and yield from 10 to 20 bushels to the acre, we must regard it as of great value; for it is the only grain which will grow on soils containing more than 85 per cent. of sand.

The *time of sowing* rye is in August or September, either after potatoes or corn, or upon a summer fallow. The quantity should be about one bushel to the acre. It may also be sown in the spring, but the winter rye is generally the most certain and productive crop. The general practice of our farmers is, to plough up sandy plains once in three years, and take a crop of this grain, and then let the soil rest for a year or two, and take another crop. This practice cannot be too severely censured. If clover were sown with the rye, on such lands, and turned in with the stubble, the soil would soon become enriched and fitted to bear any crop. If the clover will not grow, spread on ashes, plaster or lime, and as soon as the roots become fixed in the soil, there is not the least difficulty in rendering the land as fertile as you please. Instead of 8 or 10 bushels to the acre, once in three years, our farmers ought to raise, at least 25 bushels with root crops and corn in the interval.

The expense of cultivating rye, and the average product, may be stated per annum as follows.

Ploughing,	2,00	Produce on an average,	
One bushel seed,	1,25	15 bushels, at $ 1,25	18,75
Sowing and harrowing,	1,00	Straw,	5,00
Reaping,	2,00		23,75
Threshing,	2,00	Deduct expenses,	8,25
	$ 8,25	Net gain,	$ 15,50

Rye is subject to a disease called *ergot*. It is a kind of black spur in the head. It has been supposed to be a species of fungus.

Oats (*avena sativa*) are cultivated as an article of food, both for man and beast. They will grow on any soil, and are generally cultivated after corn or potatoes without manure, although some prefer to sow on green sward. Three bushels are required to the acre. The land should be ploughed once and thoroughly harrowed. Oats are a very sure crop, and may be estimated at 40 bushels to the acre upon an average. In consequence of their demand at livery stables, they usually bring a price above their intrinsic value.

The expenses of cultivation, and the returns, are generally as follows.

Ploughing,	2,00	Produce on an average,	
Seed, 3 bush. at 50 cts.,	1,50	40 bush. at 50 cts.,	20,00
Cradling and harvesting,	2,00	Straw,	10,00
Threshing,	3,00		$ 30,00
		Deduct expenses,	8,50
	$ 8,50	Net gain,	21,50

It will be seen, that this is a very profitable crop, especially as oats bring ready money, in almost any market. But if proper pains are taken, and the land properly prepared, crops of 60 bushels may be obtained. Governor Davis of Worcester, Mass. has raised 100 bushels to the acre. It should be remarked here, that there are two principal varieties; the common oat, with a spreading top, and the Tartarian, or horse-mane oat, so called, because the seed hangs in clusters on one side. As the two varieties ripen at different times, they should not be sowed together. The produce is equal in both varieties, but the Tartarian has a *shorter straw.*

Barley (*hordeum vulgare*) is extensively cultivated, partly as an article of food, and partly for malt liquors and ardent spirits. *The summer barley* is the only variety cultivated in the United States.

Barley seed, before sowing, should be steeped twenty-four hours in soft water, in order to promote the germination of all the grain and its ripening at the same time.

The soil should be rich and mellow, although it will flourish tolerably on a clay soil, free from weeds. Crops of turnips or potatoes are the best preparation for this crop. The seed should always be sowed upon a fresh-stirred soil, as early as the land will allow in the spring, and from 2 to 3 bushels should be allowed to the acre. The barley may be cradled in the same manner as oats. The value of this crop may be thus estimated per acre.

Ploughing,	2,00	Produce, 30 bush. at 80 cts. per bushel,	24,00
Seed, 3 bush. at 80 cts.	2,40	Straw,	5,00
Sowing and harrowing,	1,50		29,00
Harvesting,	2,50	Deduct expense,	11,20
Threshing,	2,80		$ 17,80
	$ 11,20		

This is probably about an average for this crop, yet fifty-four, and even sixty bushels have been produced on a single acre. When clover and grass seeds are sown with it, it is recommended to delay the sowing of the grass seed, until the barley has just appeared above the soil and then harrow it in. This will effect the barley favorably, and increase the quantity of both crops.

Buckwheat is a valuable crop, because it will flourish well on a sandy, poor soil. It is, however, but little cultivated in New England. It is one of the best crops for turning in to the soil to increase the quantity of vegetable matter. It will yield, upon an average, 30 bushels per acre, and the flour is much esteemed for making warm cakes, and brings as high a price as wheat. It is easily cultivated, and may be sown as late as July, but the flour is not always good.

Flax and hemp are cultivated to a very limited extent in this country. For a particular description of their mode of culture, the reader is referred to the agricultural publications of the day.

Rice and cotton are also cultivated in the South, but the methods of culture need no description in this connection.

Sect. 2. *Cultivation of Roots.*

The cultivated roots are the beet, carrot, turnip, potato, parsnip, onion, etc. From their influence upon the soil, and the small quantities of alkalies they extract, they are generally considered ameliorating crops. As many of them are provided with broad leaves, they extract most of their nourishment from the atmosphere and from water.

Potato. The potato is the bulb of the *solanum tuberosum*, and grows wild in the mountainous districts of Peru and Chili. Potatoes are in almost universal use, and the most valuable of root crops. In the course of cultivation, several varieties have been produced by a treatment similar to that pursued with corn. It is not consistent with our limits, to treat of the different varieties and their comparative merits. The English white, the blue, red, kidney, rohan, lady's-finger, long-red and chenango are names by which several varieties are designated. As the potato is generally propagated by eyes or the tubers, and not by the seeds, it has been a question much discussed by farmers, whether the whole potato should be planted, or only the cuttings. This question has been very satisfactorily settled by experiment. It is found that the seed end, or that opposite to the stalk, cut rather deep, yields the largest and most thrifty shoots and the most bountiful crop.*

* See experiments in Buel's Cultivator, Vol. III. p. 182.

The *seed end* is always to be prefered for several reasons. 1. The potatoes will be two weeks earlier. 2. The other part of the potato is valuable for cooking or domestic animals. 3. The eyes next to the point where the tuber is attached to the stalk, will produce only weak shoots and small tubers. Hence, as the size of the tuber will depend upon the seed, and size of the tuber from which the seed is taken, we have an easy and certain rule which we may adopt, in reference to the seed required for this crop. The quantity of seed may vary from 10 to 20 bushels per acre.

The *soil* best fitted for potatoes, is a light sandy loam ; but they will flourish well on almost any soil, especially on green sward. For culinary purposes, the soil should be light and dry, but of a deep tillage.

The *mode of preparing the soil*, is, either to turn it over after green manure or compost has been spread over the surface, or, if moist, to throw it into ridges, and plant the potatoes in drills or rows, about six inches apart. In the former case, the potatoe hills may be 3 feet by 2, with 3 or 4 seed ends in a hill. Whether potatoes should be cultivated in hills or drills, is not well settled. It is a common practice to manure potatoes in the hills or drills, but unless there is a want of manure, this process is not so good as that of burying the manure deeply under the surface. Potatoes require to be covered from 3 to 6 inches in depth, according to the moisture of the soil. The after culture should be first with the cultivator, and then with the hoe. Some recommend a flat surface, which may succeed well, if the soil is very deep and light ; otherwise, there should be large broad hills, in order to give the air and water a free circulation to the roots.

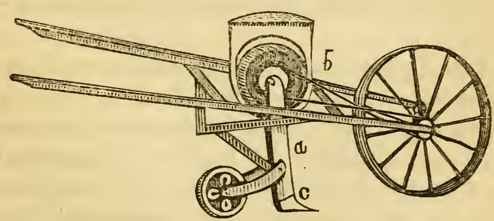
The *time of harvesting* potatoes will depend upon their maturity. They should be suffered to remain in the ground until the stalk is perfectly dry. If the tubers are taken out of the ground before they are perfectly ripe, they will be liable to wilt, or to become unwholesome before spring. The best mode of securing them, is to put them in pits, into which but a small quantity of air is admitted. When left in the ground, they are much better in the spring than when exposed to the air in cellars. Daubeny states, that they may be preserved perfectly, by freezing them up solid in the fall, and thawing them in the spring and rapidly drying them.

The following is an estimate of the value of this crop in Massachusetts. Ploughing $4,00 per acre; manuring in hill $15,00; seed, 20 bushels, worth $5,00; two hoeings, $4,00, and digging, $10,00; amounting in all to $38,00. The average produce is 200 bushels to the acre, worth at least $50,00. This would give a net profit of $12,00 per acre. In some places, the value of the crop is more than double this sum; in others, less than half of it. But $12,00 per acre may be regarded as an average profit on every acre of potatoes cultivated in the State.

Beets. There are several varieties of this root; four varities, at least, are cultivated to some extent in this country.

1. *Mangel Wurtzel.* This is the largest, and most productive of the family.

Fig. 20.



The *soil* required for this crop, is a deep, moist, clayey loam. The tillage, as in all cases with root crops, should be deep; and the sub-soil plough used, to render the earth permeable by the roots, to the depth of 12 or 16 inches. The seeds may be sown with a drill-barrow, (Fig. 20), and covered with a hoe in rows about 2 feet apart, or they may be dropped by means of a dibble. This instrument is made of wood, with a handle 3 feet long, a head like a rake, and from 6 to 12 teeth one inch in diameter; it is made so that it may be stamped down, and the holes made an inch or two deep, about 2 inches apart. A boy may then follow, and drop one seed into each hole and cover with fine mould half an inch deep. They should be sown the last of May. The after-culture consists simply in keeping the ground clear of weeds, and of thinning the plants to the distance of 8 or 10 inches. The roots should be gathered as soon as they are ripe; which may be known by the under leaves becoming yellow. They may be preserved in cellars, and fed out to farm stock.

The cost of cultivating this crop, is estimated at about $30,00 per acre; and they yield, at least 600 bushels, which, allowing a fair price for them, would leave, at least $25,00 net profit per acre.

2. The *turnip* and *blood beet* are cultivated in gardens, and to some extent in fields. They are best cultivated in ridges; that is, by throwing two furrows together, and sowing the seed in double rows as above.

3. The *sugar beet*, or white variety, is cultivated on a limited scale in this country, but it supplies France with nearly all her sugar.

This beet is a very profitable crop, and is beginning to be introduced into this country. In 1841, Mr. Tudor, of Nahant, raised a crop which yielded at the rate of more than 36 tons to the acre, or about 1,300 bushels. The value of this crop must be equal to $180,00; which is sufficient to pay all the expense of cultivation, and leave a large profit. It should be remarked, however, that the soil was put in the best possible condition, and in all cases, deep tillage is essential to success. The juice of this beet is boiled into sugar, which equals that made from sugar cane. But the chief value of this variety in this country, is to feed out to farm stock.

Carrots are beginning to be cultivated for farm stock;

their mode of culture, is in all respects similar to that of beets; they require a similar soil, and the same attention to ensure a crop. The value of carrots for field culture, is fully equal to that of beets. They will yield about the same quantity of food, and, for horses, are decidedly preferable to beets or any other roots.

The value of this crop is also beginning to be estimated, by many of our farmers. We do not see why this root is not cultivated instead of the Swedish turnip, as we believe that it is much more valuable for farm stock, especially for cows which give milk.

Parsnip. The parsnip is also beginning to be cultivated for farm stock, and requires the same treatment as beets and carrots. Parsnips are equally productive, and much better for some purposes. They may remain in the ground over winter, and be fed out in the spring. On this account, they are preferable for feeding stock late in the season. We do not know why this root is not cultivated more extensively by all our farmers.

Artichoke. The Jerusalem artichoke is a root which is valuable for light sandy soils. The introduction of it among the cultivated roots, would be of the greatest advantage to agriculture. (See p. 129.)

Onion. This can hardly be regarded as a field crop, although they are raised in great abundance near our cities. Their mode of culture is well known. They require a moist soil, and may be cultivated several years in succession on the same field.

Turnips. The introduction of the turnip among the cultivated crops, constitutes an era in the art of husbandry. Of the several varieties which are cultivated, we may select three, as most worthy of attention: the yellow, white and Swedish or ruta baga turnips.

1. *Ruta baga* or *Swedish turnip* is the most important of these varieties, and yields the largest quantity of vegetable

matter for the use of farm stock. It should be remarked, also, that there are varieties in this root. The best have a yellowish look, globular form, and have no neck or stem. The green and yellow kinds often prove abortive. The *seed* should be black and full. One pound will suffice for an acre of land. One half a pound will produce plants enough for an acre; but as the seed is liable to fail, a pound is not too much to ensure a crop.

The time for sowing is from the 20th of June to the 5th of July.

The soil best adapted to turnips, is a light, dry and friable loam; or almost any dry soil, with the exception of heavy clays.

The soil is best prepared by throwing it into drills 8 feet apart, filling the drills with short manure or compost, and after covering it with a plough, two furrows on each side, sow with a drill-barrow, p. 335. The ruta baga flourishes best on a clover ley, and may be sowed after the first crop of clover is taken. If long manure is applied, it should be covered with a plough. If rotted, it should be placed under the seed, so that the roots will penetrate it. The plants generally make their appearance in 8 or 10 days after sowing; they should then be horse-hoed with the cultivator, and the soil should be removed as near to the plants as possible, in order to destroy the weeds. The hoe should then be employed, and the plants thinned to a distance of 8 or 10 inches.

The quality of this crop depends upon the size; and what is rather remarkable, the larger they are the more nutriment they possess in proportion to their weight.

Gathering. The roots may be easily drawn with the hand. The tops and tap-roots should be cut off, and they should be permitted to dry on the ground, until the dirt may be separated from them. They should then be stored in pits, 3 feet in breadth, and covered with a good thickness of earth. The value of this crop is variously estimated by different farmers.

The products are, upon an average, 600 bushels per acre. Some estimate the net profit at 80 dollars per acre; but their value will vary in different places and seasons. There is no doubt but that it is one of the most valuable crops raised by the farmer, although they are much less esteemed than they formerly were.

Use. This root is excellent for all kinds of farm stock. They are said to be useful for fattening hogs, cattle and sheep. They may be fed raw, sliced, and a small quantity of salt sprinkled over them.

2. *The white* turnip requires a similar soil and treatment; but may be sowed as late as the 25th of July. They are not so productive as the preceding, but are excellent for a second crop, or for feeding cattle in the fall; by which course light soils may be improved.

3. *The yellow varieties* may be sown about the 15th of July, and are richer than the white. Sinclair estimates the amount of nourishment in 64 drachms as follows.

White tankard	76 grs.	Store or garden	85 grs.
Common white loaf	80 "	Ruta baga	110 "
Norfolk white	73 "		

The following table gives the nutritive properties of several varieties. The green-top yellows being taken as a standard.

Species and Varieties.	Should weigh by Size & Standard.	Actual Weight.
	lbs. oz.	*lbs. oz.*
Green-top yellow	16.00	15.00
Swedish or ruta baga	11.2	13.12
Red-top yellow	12.00	12.10
Dalis hybrid	13.12	12.00
White globe	20.8	15.8
Red-top white	16.8	13.00
Green-top white	8.7	8.8
White tankard	16.	14.
Purple do.	12.10	11.8

This table shows the superiority of the ruta baga over all the other varieties. It yields about 6 or 7 per cent. of its whole weight of nutritive matter, while the white varieties afford 4 per cent., and in the largest roots only 3½ per cent. of their whole weight; hence, one acre of the Swedish variety is equal to one and a half acres of the white. "No person," says Lord Kaimes, "ever deserved better of his country, than he who first cultivated turnips in a field. No plant contributes more to fertility."

It appears from the investigations thus far made, that roots are by far the most profitable crops cultivated by the farmer; and that their more general introduction would both increase the value of the soil, and the quantity of productions from the farm, from the dairy and from farm stock.

Sect. 3. *Cultivation of Grasses.*

Grasses constitute the principal food of farm stock, and, reciprocally, the food of future crops; hence, their cultivation must be an important branch of agriculture in almost every country, but especially in countries in which from 4 to 6 months of the year, the earth is destitute of herbage; as it is in most temperate and cold climates. The points to which the farmer should direct his attention in the cultivation of the grasses, are the selection of seed, and soil adapted to the character of the plant; the preparation of the soil; the sowing of the seed; the time and mode of securing the crop, and its comparative value. The cultivated grasses may include what have been called *herbage plants*, of which the *clovers* and *lucern* are the only kinds* which have been cultivated in this country.

I. *Clovers.* There are three species of clover, usually cultivated by the farmers of this country, and two other species, which have been cultivated in Great Britain, in which country clovers were first cultivated in the 16th century.

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* Sanfoin, bird's-foot, trefoil, parsley, burret, rib-wort, plantain, broom, wild-flower, yarrow, etc. are of this class; but are of little importance, with the exception of sanfoin, which requires a chalky soil. The bird's-foot and trefoil have been but partially cultivated among us.

1. *Red clover* (*trifolium pratense*) is a well known biennial, and sometimes, if not permitted to seed, a triennial plant. It does not mature its seeds well in the first of the season, and hence it must be fed until June, or else the seed must be obtained from a second crop, which will ripen in August, or the first of September.

The soil best adapted to red clover is a deep sandy loam. The long tap-roots will extend downward to a great depth; and hence deep dry soils, of almost any description, are well suited to it, although it prefers one in which there is a large quantity of lime.

The quantity of seed depends upon the soil; it is usually, in this country, 10 lbs. to the acre; in Flanders, 6 lbs.; and, in Great Britain, 14. The greater the number of plants which can be made to grow, the finer and better the quality of the hay.

The time of sowing clover seed is in the spring, either with a grain crop, and before the last harrowing or bushing, or upon winter grain, just as the snows are leaving, in March or April. The sowing should be followed by a light harrow or roller. The latter especially will be of essential service to the grain crop. If the soil is wet, or a stiff clay, the seed should be sown in mid-summer with buckwheat. The practice of sowing clover seeds in the autumn, should be discontinued, as the plant rarely attains sufficient strength to survive the frosts of winter.

During the growth of clover, the crop may be much increased by sprinkling the surface of the young shoots, in the spring, with plaster, one bushel to the acre; and if the crop is continued for several years, a top dressing of lime or ashes will prove highly beneficial.

The time of cutting clover, when intended for hay, is at a period when it is in full bloom. It is then much lighter, but the stalks are more tender, and will fatten stock much faster, than if permitted to remain until the seeds ripen. And further, two crops may be cut the same season, one for hay and the other for seed, or both for hay.

The methods of making clover into hay are variously described by different practical farmers. The following seems to accord best, both with theory and the experience of the best farmers. After the swaths are turned, they should be spread just so that the heat of the sun will wilt and partially dry the leaves; the clover may then be placed in grass-cocks, about 6 feet high, using a fork instead of a rake. By this means the cocks may be formed with the straws all inclining downward, so as to carry off the rain. The rake may then pass over the ground to gather up the remainder. The cocks should always be formed before the leaves begin to crumble, and before the dew begins to fall. The cocks may now stand from 36 to 48 hours, until they grow quite warm. They should be opened after the dew is off, spread out 6 inches thick, turned between 12 and 2, and, if the day is good, gathered into the barn one or two hours afterwards. A small quantity of salt, 3 or 4 quarts to a load, should be mingled in the mow.

The advantages of this course have been tested by the experience of the best farmers. The reasons for it are found in the *size* of the *stalk compared with the leaf*. When spread, and exposed to a hot sun, the leaves dry up to a crisp, and fall off before the stalks are sufficiently dried to be placed in the mow, without the danger of heating. In the cock, the heating process commences, and all parts of the plant are dried alike; if fermentation is arrested at the proper time, it will not be so liable to heat in the mow, and hence will continue green, fresh and sweet until used.

2. *The cow grass* or southern clover (*trifolium medium* or *trifolium Pennsylvanicum*) is a perennial, resembling the red clover, but shorter and with paler flowers. It is a fortnight earlier than the preceding. Hence two crops may be cut the same season, even if fed until the 20th of June; or if

the first crop is taken by the 28th, the second crop will mature its seeds.

3. *White clover* (*trifolium repens*) is also a perennial and a very sweet and useful plant; it should be sown more frequently than it is. It is mostly found in pastures and furnishes the best of food for grazing. The *yellow* and *scarlet* clover are not cultivated among us, though the former is in England. Clover is admirably adapted to an alternating system of husbandry, as two crops may be cut in one season. As its roots penetrate and divide the soil and exhaust but little from it, we are astonished that our farmers do not cultivate it more, and are disposed to subscribe fully to the sentiment of the Flemmings, that "no man in Flanders would pretend to call himself a farmer without clover."

4. *Lucerne* (*medicago sativa*) is called in this country, *French clover*. It is a perennial plant, sending up several small shoots resembling clover, but with spikes of blue or violet flowers. It was early cultivated by the Romans, and is now cultivated in many countries of Europe, South America and the United States. The seed of lucerne is obtained in the same manner as that of red clover, from the second crop, and is contained in pods which are easily threshed.

The soil should be siliceous, with deep tillage and dry sub-soil. No soil is too rich for it, and unless it is well prepared by finely pulverizing it, the crop is liable to fail. Loudon recommends trenching, but it flourishes well after potatoes or roots of any kind, provided the manures are green and deeply ploughed in.

The time for sowing varies from the 1st to the 20th of May, and the *quantity of seed* is from 15 to 20 lbs. per acre when sowed broad-cast with rye, and 10 lbs. when sown in drills, three feet apart, and other crops (as roots) cultivated between.

The after culture of this crop consists in harrowing, twice a year, after the first year (if sown broad-cast), and in removing all the weeds. But if sowed in drills, it must be cultivated with the cultivator and kept clear of weeds. Ashes, gypsum and lime are excellent top dressings.

The time of cutting and the mode of curing, are precisely the same as for clover, but it is fed to the best advantage in a green state, or for the purpose of *soiling*, see p. 64. It may be cut for this purpose from three to five times in a single season, and the quantity cut from one acre, has been stated at from 5 to 8 tons, in one season. The soiling of one acre is sufficient to keep from 5 to 6 cows during the soiling season. It is therefore an invaluable plant, where pasturage is scarce or dear. But it is also an excellent hay, equal in all respects, according to some farmers, to clover.

5. *Timothy* (*phleum pratense*) is better known in this country as *herdsgrass*, and in Europe, as *meadow cats-tail.* It is a hardy, perennial plant, growing with great luxuriance in our climate and soil. It is the principal foraging grass of the Northern States.

The seed may be obtained by reaping the tops down from 10 to 12 inches and cutting the remainder for hay.

This grass flourishes in almost any soil, capable of cultivation, but as the seeds are small, particular care should be taken to pulverize the soil, and to cover the seed lightly with a bush-harrow or with the roller.

The time of sowing the seed may be, either in the spring, with the spring grain, in the fall with winter rye, or just before the ground thaws in the spring. It is often sown with clover, a very improper practice, because the clover is ripe at least two weeks earlier than the timothy. The quantity may be from 4 to 5 lbs. to the acre, sown broad-cast.

Timothy may be cured, by spreading and cocking over night, and should not be cut till its seeds are formed, hence it exhausts the soil more than the clover. But the value of this grass is increased by allowing it to remain on the ground until the the seeds are in the milk; still, if it is cut green, there is a compensation in a greater amount of the after-crop, which had better be fed on the ground, than removed as *rowin.*

6. *Redtop* (*Agrostis vulgaris*) is the *herdsgrass* of the Middle and Southern States. It is indigenous to the soil, perennial, and well adapted, both for pastures and meadows, and especially for reclaiming swamps and wet or moist lands. It springs up spontaneously, but may be sown with timothy, and in the same way; and, as they are ready to be cut at the same season, they furnish the most valuable hay. The white-top, or fowlmeadow, is said to be a variety of this species.

7. *American cock's-foot* or *orchard-grass* (*Dactylis glomerata*) is one of the most permanent grasses. It is rather coarse and whitish in appearance, with broad leaves, and seed glumes resembling a cock's foot, from which it receives its name.

This plant abounds in seeds, but they are very light, so that two bushels are sown on an acre.

The best *time and mode of sowing* it, is with clover, because its growth is early and rapid, and both are fit for the scythe at the same time. It may be cultivated and cured in all respects as clover. But it appears best fitted to pasturage, both because of its rapid growth, and because it is liable to grow coarse and harsh. Its highest value is obtained by keeping it cropped closely with sheep, but when cut early with clover, the after growth is very abundant and of great value; $\frac{2}{7}$ of its value is diminished if permitted to ripen its seeds.

8. *Tall oat-grass* (*Avena elatior*) is placed by Mr. Taylor and Mr. Muhlenburgh at the "head of good grasses." The latter says, "it is the best of grasses, and the earliest for green fodder and hay."

The seed is liable to waste if not collected in season. It may be sown with grain crops in the spring, six pecks to the acre, according to Sinclair, on a strong tenacious clay. But a clover soil is well adapted to it. It appears to be better adapted for pasture than for meadows. See Complete Farmer, p. 228.

9. *Sweet-scented vernal grass,* (*Anthoxanthum odoratum*), and *meadow foxtail* (*Alopecurus pratensis*), are foreign grasses. The former is rather scanty of herbage, and is used for cow pastures; and the latter, being much more abundant in produce and nourishment, is cultivated in England; but both have been introduced into the neighborhood of Boston and Philadelphia, and have now become a part of the ordinary herbage of our meadows.

10. *Rye grass* (*Lolium perenne*) is cultivated in Scotland, and the north of England; "and forms the principal seed sown with clover." There are several varieties of this grass, but it has not as yet flourished well in our climate. It requires a moist atmosphere, and is not considered worth cultivation, unless in elevated and moist places. Our best farmers in New England, prefer to sow all grass seeds, with the exception of clover, as early as possible, after the crop in September, and after the land is ploughed.*

The above are our principal grasses, but the common herbage of our meadows consists of several other varieties. Several species also are cultivated in other countries, but are not of sufficient importance to need further notice in this connection. In conclusion, we would call the attention of our farmers to the improvement of their swamps for natural meadows. It can be shown, that such lands are most valuable for this purpose, and may be made to yield a profit from twenty to fifty dollars per acre annually.

Sect. 2. *Relation of Farm Stock to the Cultivated Crops.*

The subject of farm stock, is intimately related to the cultivation of farm crops. The one cannot well flourish without

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* See Fourth Report of the Agriculture of Massachusetts, p. 233.

the other. The suggestions which we would make, relate to the mode of improving stock.

What then is the best method of improving the farm stock? We answer, by improving the farm crops. The thrift of farm stock depends more upon a proper attention to the preparation of proper food, than to any other circumstance. Why is it, that farmers must send to Saxony for sheep, to Berkshire for swine, to Durham or Yorkshire for cattle, and to some other foreign country for seeds? simply because the *farm* is not attended to, because the soils and crops are neglected. There is neither the *variety*, *quantity* or *quality* of products, which are necessary to improve native breeds, or to keep up the thrift and perfection of those which are imported. The consequence is, that the imported and improved animal or plant will flourish for a while, but will gradually deteriorate, until they both sink below the native stock; a new importation must be made, and, in all such cases an extravagent price paid. Is it not a just subject of reproach to New England farmers, that they should thus be made the dupes of speculation, with regard to their farm stock; while they have a soil, climate and sources of improvement, so favorable for the rearing of stock, that they ought to be a *pattern* for the rest of the world?

It is a law of the animal and vegetable kingdoms, that neglect will produce deterioration. This may not be perceptible the first generation; the second will begin to show it; the third still more. And in the course of ten or twelve generations, the reproductive and vital powers will be either wholly exhausted, or require double feeding, to enable them to perform their offices.

On the other hand, when the animal or the vegetable has thus become deteriorated, proper attention will not remedy the evil in a single generation. The progress of improvement is slow; and hence it is, that improved stock, and improved seeds, result from a long course of careful culture. It requires at least as long, if not longer, to restore their wasted energies, as it does to destroy them.

The great mistake with most farmers is, that they attempt to cultivate *too much land.* They are not impressed with the importance of investing capital in their farms and farm stock for future use. They look not to a future and permanent fertility and thrift, but to an *immediate gain.* The best stock are the fattest, and of course will bring the most money in the market ; they of course are sold off, and disposed of by the butcher and his customers. The best hay must go to market, for that which is inferior will keep the stock alive. The sure remedy for these evils, is to have no inferior productions; and then we may hope to send our live stock and seeds to other countries, instead of bringing theirs to our own.

It is not intended by these remarks to dissuade farmers from attending to the improvement of their farm stock, but simply to point out the best mode of improvement; and to show the folly of attempting to retain, for any length of time, the perfection of any improvement in stock or crops, without attending to the preparation of food for them.

The true method of improving stock, is to improve the farm ; so as to retain any advance that is made, rather than to be constantly running out one kind of stock, and introducing new kinds.

There is one great defect in the *mode* of introducing new stock ; but one or two of a kind are first introduced. These are deteriorated by mixing with those whose reproductive energies are weakened or exhausted. By this course, the farmer expects to procure a new, and better breed ! The practice of farmers in this respect, reminds us strongly of the resolutions passed by the Irish court : "Resolved, that we build a new jail. Resolved, secondly, that the new jail be made from the old one. Resolved, thirdly, that the old jail remain standing, till the new one is built."

Farmers resolve to make new breeds. They then resolve to make them out of their old breeds ; and then resolve to let their old breeds remain just as they are, until the new breeds are formed. A far better series of resolutions would be to resolve, 1. to understand what their crops require ; 2. to till less land, and till it better ; 3. to furnish for their farm stock better provisions ; and finally, retain for farm purposes the best fodder, the best seeds, and the best stock.

We would remark, in conclusion, that there are other animals, aside from those domesticated by the farmer, which bear an important relation to the cultivated crops ; we refer particularly to foxes and crows ; as there is in many places, a bounty paid by the State for their destruction. It would be far wiser policy, to expend the same bounty for their protection. A single fox in a meadow will often save a ton of hay in one season, by destroying the *mice ;* while crows, and other birds perform an equally valuable service, by destroying seeds, worms and insects, which would otherwise injure or destroy the crops.

CHAPTER IX.

HORTICULTURE.

Horticulture is so far a branch distinct from Agriculture, that it has not only received a characteristic name, but is generally treated of by writers in a separate treatise. We should have said nothing upon the subject in this work, but for the fact that a few suggestions might be useful to the common farmer, who does not make gardening a particular business, but wishes to understand several important processes and principles connected with the art. It should be remarked, too, that the most important natural laws apply alike to Agriculture and Horticulture; and that a few suggestions here, may embrace what would require a separate book to unfold without such connection. It is to be hoped, therefore, that what we may be able to say on this branch of the subject, will not be wholly out of place, and will contribute to the advancement of an art which is every day becoming more and more important. The subject may be treated of under the following heads. 1. Selection of seeds, and the preservation and improvement of races. 2. Propagation of species, by seeds, eyes, cuttings, grafting and budding. 3. Processes of pruning, training, potting and transplanting.

Sect. 1. *Selection of Seeds, and Propagation and Improvement of Races.*

The quantity and quality of vegetable productions depend as much upon the proper selection of seed, as upon any one operation of the rural art. This is an important point for the attention of the common farm; but indispensable to the success of the gardener.

I. *The maturation of the seed* is a vital action, and generally proceeds without any difficulty, when plants are left to their natural soil, climate and culture. But cultivated plants often fail to mature their seeds; or, if they are matured, their vital powers are weak, and they produce but sickly offspring. The causes of sterility are,

1. *The unnatural development* of some organ near the seed vessels, by which the nourishment designed for the seed is withheld. Instances of this are found in the pear, pine-apple and plantain. The nourishment goes to the fruit; in which case a portion of it, or of water, should be withheld, so that the seed may receive its proportion. Hence it is, that some plants, as the pine-apple, will only mature their seeds in a poor soil. The tubers of potatoes often abstract nourishment from the seed, and the seed from the tuber; the same is true

of other roots. Hence, if seeds are required of such plants, they will be much more perfect if the tubers are removed.

2. *Deficiency of pollen.* Some plants become so debilitated by cultivation, that the pollen of the stamen will not fertilize the stigma of the pistil. In this case, the only remedy is to bring pollen from some more vigorous plant, and apply it, by artificial means; a process only applicable to garden plants.

3. A moist, cold atmosphere, will prevent the pollen from being formed; and, if formed, from being thrown upon the stigma. The fertilizing influence takes place only when the plant is exposed to the warm dry air. Sometimes the presence of insects is necessary to convey the pollen to the stigma; and if they are absent, sterility will follow.

4. The most frequent cause of sterility is the *monstrous condition of the flowers* of many cultivated plants. The flowers are nothing but modifications of the leaves; the stamens become florets in the course of cultivation, as always happens in double flowers. Now it is evident, that when the stamens are thus all changed, they cannot secrete pollen, and of course there is nothing to fertilize the stigma. The stigma itself, also, becomes changed. This can be remedied only by planting, near by, the same species of plant which have either stamens or pistils, as the case may be, and the requisite quantity of pollen may be thus furnished.

5. Many cultivated plants are grown in a climate different from that in which they grow naturally. The process of watering, also, often exposes the flowers and fruit organs to decay.

Such are some of the causes of the sterility of plants; and it is evident, that if these and other causes do not operate wholly to prevent seeds from ripening, they may weaken their power of reproduction. As weak seeds will produce weak plants, resource should be had to every means possible, to give the highest degree of life and vigor to these indispensable bodies. Generally, the best seeds may be found by examination; the plumpest and most completely formed should be selected. Or they may be floated on water, and those only selected which sink to the bottom.

But this mode is not the best possible one for garden seeds and fruits; for the *vital principle* in seeds may be increased by removing branches or fruits that are near; by exposing the seed vessels to light; and by prolonging the period of ripening.

It is a well established law, of animals and vegetables, that an unhealthy parent produces a diseased offspring; the seed will take after its parent. A vigorous parent will yield "a healthy progeny in all their minute gradations and modifications; hence varieties and monstrosities are matters of generation and constant reproduction." If seeds are to be sown immediately, it is better that they should not be quite ripe; for there are two periods in the latter part of the organization of seeds, one before they are fully matured, when they possess the germinating power, and will flourish well if immediately sown; and the other, when they are fully ripe, in which case they lay up a large portion of carbon, and will not germinate until some of it is abstracted by the decomposition of water. Hence, if seeds are to be kept for any considerable time, they should be perfectly ripe, and kept perfectly dry. They will then preserve their vital powers entire, for a great length of time. The vital energy differs in this respect from 1 to 17 hundred years or more, p. 42.

If seeds are to be packed up, it is best to put them in coarse paper, enclosed in coarse canvass bags and exposed to the air, the seeds being made perfectly dry before packing.

II. The *preservatian of the races* or *varieties* of plants by seeds, involves many important laws of vegetable life, which are of great interest to the practical gardener. This process is applicable to all plants; but is more important, and more difficult in the case of annual plants, which comprise those most cultivated by the farmer and the gardener.

It is the general law of seeds, to propagate *species only* to which they belong; hence, we cannot rely upon any particular *variety* of the species. There is, however, a tendency to produce a seedling more nearly resembling the parent, than any other variety of the species. There will, therefore, be a majority of plants either like, or better than the parent. By selecting these for seed the second year, and obtaining in each successive year those most resembling the original seed, the variety will be in time established. Every *cultivated* grain has doubtless passed through successive stages of perfection in a similar way, and a new habit has become *fixed*. See p. 324.

It is easy to learn how different varieties are produced; early or late varieties, for example. If a plant has been cultivated for years in a warm, dry soil, where it ripens in 60 days, it will acquire an excitable *habit;* and when sown in a colder soil, will for a season, mature its fruit much earlier. "The reverse will happen to an annual from a cold, wet soil." But in both cases, if the plant be continued in the same soil, it will change its habits; hence, seedsmen obtain seed from warm, dry soils, for their early vegetables; hence too, we may raise on cold lands certain crops, as barley or Indian corn, provided the seed be procured from warm, and dry soils. But how can these varieties be preserved as their tendency is, to revert back to their wild state?

1. The best mode of preserving the variety is, to transplant the plant shortly before it goes to seed. By this means the character of the variety will remain.

2. Another mode of preserving the variety is to cultivate the crop so far from any other crop of the same species, that there may be no intermixture of the pollen. This substance is conveyed a considerable distance by the winds, and by insects; hence, seeds should not be saved from one or two individuals standing alone in a garden, as bees and other insects

will be more likely to introduce the pollen of the same, or similar species from a distance.

III. *Improvement of varieties* or *races*. The remarks already made, apply to the *improvement* of the races or varieties. A fixed improvement in the quality of the produce of a plant, can be obtained only in two ways; either *accidentally*, or by the process of *muling*.

1. Accidental varieties often spring up, we know not why, but when they occur, they indicate a change in the organ, which is sometimes propagated in the seed. The nectarine may thus have been produced from the peach.

2. But the most direct means of establishing new breeds or varieties, is by a process called *cross-breeding* or *muling;* that is, by selecting the most vigorous plants of two varieties, and putting the pollen of the one upon the stigma of the other. A new variety will thus be produced, which may be perpetuated as above described. In this way, nearly all our varieties of squash and mellon are produced; and some of the most gaudy and beautiful flowers which adorn our gardens. There is no end to the different varieties which may be formed by this process.

Sect. 2. *Propagation by Eyes, Cuttings, Grafting and Budding.*

The natural mode of propagating plants, is by means of their seeds; but, as we have seen, we cannot always rely upon that mode of continuing the same variety. Hence, propagation by other modes has been resorted to, as the most certain means of preserving and continuing any variety desired. These modes recommend themselves to our attention by another circumstance; the time required to procure the fruit from any species is much less, than when the seed is employed.

Annual plants must be propagated by their seeds, or by their tubers. Biennial and perennial plants, may generally be propagated in a much more expeditious manner by other modes. Some of these methods will form the subjects of this section.

I. *Propagation by eyes and buds.* The propagation by any other means than by seeds, depends upon the presence of leaf-buds, or what are technically called "*eyes*," which are in reality, the rudiments of branches attached to the stem or tuber. These eyes are capable, under certain conditions, of producing new parts, of exactly the same nature, as those from which they sprung.

Sometimes, as in the lily, they separate from the plant, and take root, producing an independent plant; at others, they remain on the stem, and send out branches, flowers and fruit.

In theory, all plants appear capable of being propagated in this way. But the fact is, that the vital power of buds is sufficient in only a few plants, to enable us to be successful; only two are by this practice re-produced; these are the potato and the vine. The method of propagation by the former, is too well known to need description; that of the latter, is as follows. The eye, with a small portion of the stem, is commonly taken, and placed in earth, with a bottom heat of 75° or 80°, in a damp atmosphere. In a short time, it shoots upwards into a branch, and sends down roots to establish itself in the soil. It is necessary, that a considerable portion of the albumen should be planted with the eye in this case, as the bud itself does not contain matter sufficient for its development; this, it must obtain from the stalk; and, if the quantity is increased, that is, if the whole vine is buried, the sprout is much more vigorous. There are a few cases, in which the buds are fixed in embryo upon the leaves, so that new plants may be propagated from them, but this mode is never resorted to in practice, unless it be in some species of the cactus.

II. *Propagation by cuttings* or *slips* is the most common of all modes, with the exception of grafting. This process depends upon the eyes or buds, and consists simply in cutting off a branch, inserting it in fine mould, and subjecting it to a moist, warm air. The roots, as well as the branches come from the buds. This is shown by the fact, that the vine, when it grows in a warm, damp stove, emits roots into the air which proceed from buds. Roots, however, seem to be formed by the action of the leaves; branches are developments of buds, and the buds are maintained by the matter in the tree.

Cuttings may be placed in fine mould in pots, and then either subjected to a moderate hot-bed, or covered with glass and exposed to the direct rays of the sun.

Layers are similar to cuttings, the only difference is that they are attached to the parent branch, until the roots are established. The branch is bent into the earth and half cut through at the bend, and as soon as it has taken root it is separated from the parent stalk.

Suckers are branches thrown up from the base of the plant, and are one means of continuing and propagating the same varieties.

III. *Grafting* and *budding* are operations, which consist in causing one plant to grow upon the stock or branch of another. This process differs from that of propagation by eyes and cuttings, only in the circumstance, that in the former case, a part of one individual, containing an eye, is inserted into another of the same family, and the two form one unique compound individual; while, in the latter case, the eye is made to send its roots down into the soil, and to derive its support from it. One process, is the inserting of an eye into another tree, the other is, the inserting of it into the ground. The object of these operations, is the same as that of layers, cuttings, etc., to continue the same variety, or to improve it. It is particularly applicable to those plants or trees (as the apple, pear, peach, etc.) which are not easily propagated in any other way. There are also many advantages secured, especially in the character of the fruit.

1. Some varieties or species are much more hardy than

others, and more delicate varieties may be ingrafted upon them, and partake of their strength and vigor. Thus it is, that many varieties of the vine are propagated; as the most choice kinds are found to grow better upon strong robust stalks. So it is with some species of the pear, peach, cherry, etc. The wild plum stock is prefered for the insertion of buds. The wild apple is also prefered for setting grafts.

2. The peculiar qualities of some plants can be preserved only by this process; thus, for example, certain varieties of the rose will become plain, if they are not budded into other stalks.

3. The fruit may be obtained much earlier, and sooner, by these processes than by any other. In fact, Mr. Knight has succeeded in transfering the buds of one plant to another, so as to produce fruit and flowers the same season. Fruit trees do not require more than three years, and they often will become fruitful the second year after being grafted.

The modes of performing these operations are various, but with regard to the majority of fruit trees, it is a very simple process.

Fig. 21.

Operation of grafting. The object of the operator in this case, is to cause the branch or graft of one tree to unite with the stock or limb of another tree. Varieties of the same species are united the most readily; genera of the same natural order come next, beyond which the power does not extend. Thus pears work well upon pears and quinces; upon apples and thorns, they will grow, but not so well; while on plums, they cannot be made to grow.

2. *Whip grafting.* This is a very common kind of grafting (Fig. 21). "It is performed by heading down a stock, paring one side of it for the space of an inch bare, and then cut-

ting obliquely towards the pith from the upper end of the pared part. The scion, *c*, is cut obliquely to correspond to the part pared, *d*, and then a tongue made to fit into the slit in the stock. Care should be taken to have the bark of the scion exactly fitted to that of the stock, and then the scion may be covered with a cement of rosin, beeswax and tallow, and bound firmly together. The sap will pass up into the scion, and its buds will develope themselves; the prepared nutriment will then descend and cover the wound where they are united. This process is said to be far superior to the process most common with us.

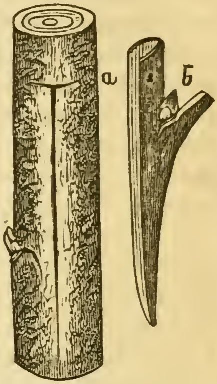
Fig. 22.

2. *Crown grafting.* This process consists simply in heading down a stock horizontally (Fig. 22), splitting it open in the centre, *b*, and then cutting one, two or more scions, *a*, so as to fit in exactly like a wedge; care being taken to have the bark of the scion and that of the stock exactly coincide. The whole is then covered with clay, or with the cement above spoken of, and the scion is held in its place by the force of the wood, in the same manner as a wedge. This process often leaves too large a wound, and the parts are not always healed over and made firm. It is, however, the most expeditious way, the most simple and generally the most successful.

3. *Saddle grafting.* Lindley recommends Mr. Knight's mode of saddle grafting, which, although more tedious, is preferable to either of the preceding modes. It consists in paring the sides of the stalk obliquely into the form of an inverted wedge, and then cutting the scion so as to slip it directly into the stock, the bark of both exactly coinciding. By this mode, the greatest quantity of surface is brought into contact, and the sap can pass up and down with the greatest facility. The scion must be kept in its place by a ligature, and the water excluded by cement. As the graft stands

astride the stock, it is, when united by the wood, firm and straight. But in all cases, success will depend upon the exact coincidence of the scion and the stock, in their inner barks and alburnum, in which the sap flows up, and the cambium down, and where the process of assimilation takes place.

Fig. 23.



4. *Budding* consists in introducing a bud of one tree into the bark of another. The process is as follows: An incision is made (Fig. 23), through the bark to the wood, and then crossed at the top *a* with a similar incision. A bud is now selected by paring it from the branch, taking care to cut a small quantity of the alburnum directly under the eye, and a portion of the bark, *a*. This is then inserted below the bark of the stock, until the bud is in contact with the wood, and the upper lip of the wood in the stock is made to coincide with that of the bud. The whole is then bound by a ligature. The object in this process is, to bring in close contact a large surface "of young organizing matter," and as the bud is thus freely supplied with nutriment, it soon unites by the edges, and the following spring developes itself in the form of a branch. The period for budding is generally about the middle of August, or at a time when the bark will easily peal from the stock. In selecting stocks for grafting and budding, regard should be had to the soil and climate.

Sect. 3. *Pruning, Training, Potting and Transplanting.*

I. *Pruning.* The object of pruning is to remove branches and leaves, so as to contribute to the beauty, health and productiveness of the plant or tree.

1. The effect of removing a branch, is to turn the sap into the neighboring organs, or into some other part; hence it is necessary to cut a useless branch fully off, so as to destroy the buds near the base. If this is not done, these buds will put forth *several* branches, instead of the *one* which is taken away. When the nourishment is thus driven into the neighboring organs, they sometimes throw out branches, which will bear abundant fruit the next year; this is the fact with the filbert. The peach, also, may thus be rendered both fruitful and much longer-lived, even in climates unfavorable to its growth. Apples, pears and plums are rendered vigorous and strong by pruning. This effect is sometimes secured by simply squeezing the ends of the young limbs, just so as to prevent their elongation, and to direct the matter to other parts, or to the maturing of the seed. If the shoots are allowed to increase, the buds will not form for the next crop. During the ripening of the fruit, especially, care should be taken that the buds and sprouts in the vicinity are removed, or twisted to direct the nourishment to the fruit.

2. The effect produced upon one part by abstracting another, is seen further in the quantity and quality of the fruit. If all the fruit of a plant is removed from it one year, it will be more abundant and of a better quality the next year. Hence we see in nature, that orchards so exhaust themselves in their season of bearing, that they are obliged to rest the next year to recover energy for a succeeding crop. Of two branches, if one is cut off, the other will grow with more vigor. This doctrine lies at the foundation of all the processes of pruning, and enables the gardener to equalize the crops and the rate of growth of all parts of the tree. If, for example, when orchards are disposed to bear only every other year, a part of the fruit were abstracted in the bearing season, some would be produced in the unfruitful season; and, after a little time, a habit of producing a moderate crop might be induced

and established. This, of course, would be more valuable than one heavy crop once in two years.

The utility of trimming fruit-trees and vines when young, depends wholly on the principle now considered.

In pruning some trees and vines, the plant is exposed to what is called *bleeding;* this, if not prevented by covering the wounded part, will injure and perhaps destroy the plant. One mode to avoid this, is not to wound such trees when their sap is flowing freely. Another is, to dissolve some gum shellac in alcohol, and with a brush cover the wood and prevent the issuing of the sap.

In performing the operations of pruning, reference should be had to the character of the tree. Some trees bear fruit on the branch which grows the same year, as the walnut. A second class, as the filbert, grows on the wood of the previous year; while a third class, as pears and apples, are produced from branches which are several years old. Hence different parts should be removed from each of the different families.

The season for pruning is either in mid-winter or mid-summer. The object of the former method is to thin and arrange the branches; that of the latter, to remove superfluous branches or aid in ripening the fruit, and in forming the fruit of the succeeding year. It may be done at other seasons, as early in the autumn, or when the tree is in blossom in the spring. It should never be done when the sap first begins to flow in the spring, because the tree wants all its leaves to commence the process of nutrition with vigor.

It has been a question among gardeners, whether trees which are transplanted should be pruned? This question is easily settled theoretically. We know that the leaves are wanted to enable the plant to put forth its roots; for the nutritious matters must go through a change in the leaves, before they descend to the roots. Now if the leaves are diminished by pruning, the power of the transplanted plant to take root in the soil, is much diminished. The roots should be trimmed rather than the branches, although no root should be removed unless it is mutilated. If young trees, when transplanted, are trimmed at all, it should be done in the fall, when the quantity of nutrition laid up in them enables them to sustain such losses as they must suffer in the process.

Root-pruning, however, may be advantageous to trees which produce leaves rather than fruit; and some gardeners have thus rendered their trees fruitful.

There is a peculiar kind of pruning, called *ringing*, that is, the removing of a ring of bark, at certain seasons, for the purpose of stopping the sap as it descends from the leaves, and of turning it either to the formation of fruit-buds or fruit, as the season may be. This operation, however, although it often increases the quantity and quality of the fruit, endangers the life of the tree, and is rarely resorted to. The same effect is sometimes produced by placing a heavy stone in the fork of the limbs. By the pressure it exerts, and by the compression it gives to the limb, it obstructs the free circulation of sap, and thus increases the quantity of fruit.*

II. *Training* is an operation wholly artificial. It has for its object the placing of a plant in a position different from what it could ever attain of itself, in order to gain the advantage of light, heat and support. Hence plants are generally trained or made to grow by a south wall, where the temperature is more equable, and where the winds are shut off so that perspiration or evaporation (a frequent cause of injury) is more equal and moderate.

1. By thus exposing a tree to a warmer atmosphere, the sweetness of the fruit is much increased; hence plums, pears and grapes are much sweeter grown on walls with a southern exposure.

2. By training, the circulation may be impeded, and the

* Lindley.

fruit increased in quantity. Thus it is found, that when the branches are made to grow downward, they will grow less vigorously, but will also produce much more fruit, because the circulation is thus impeded.

3. In the case of grapes, it is found, that the fruit is increased, by training the top branches at a great distance from the root. The tops of tall trees are more fruitful than the side branches, owing to their distance from the roots.

The trees which are benefited by training, are such as are properly climbers, as the grape; but trees whose erect posture shows that they were made to be rocked by the storms, are always injured by this process.

III. *Potting* is the growing of plants in small earthen vessels or tubs. The condition of the roots, in this case, is different from that of their natural position in the soil. This process, for most plants, is wholly unnecessary. The principal use of it is to give a start to some plants, at a period when they cannot be placed in other conditions. The plant will exhaust the soil, which must be changed frequently, or they will become sickly. If plants are placed in large tubs, they will flourish much better and for a longer time. The cases where potting is useful, refer to rare plants, or to those which will not endure the frosts of winter, and to plants which are to be transplanted. In the latter case, potting answers instead of a hot-bed.

IV. *Transplanting*. This is an important process; and one in relation to which, correct practice leads to the most useful results. A few remarks must suffice here, upon the transplanting of trees.

These relate to the time and manner of performing the operation. In our country, the season most desirable, is the spring; and during a moist or rainy day. In some countries, the fall is chosen, because the evaporation from the tree is much less in the autumn, and early part of winter than in the spring. But the frosts, by up-heaving the earth and the roots, do more injury, than can arise from the different states of the atmosphere.

It has been customary to prune trees, at the time of transplanting; but it is at least a very doubtful practice. The branches contain the leaves which are necessary to prepare the nutriment which is stored up in the autumn, for assimilation. If, therefore, we cut off the branches, we diminish that power which is first wanted in all its force, to meet the demands of life at this critical period.

But the most important point to be attended to in a practical way, is the preparation of the ground, and the mode of locating the individual in its new home. For most trees, the soil should be rendered mellow and rich, for a considerable distance around. The pits should be made from 3 to 10 feet across, according to the size of the tree. The roots should be left free, to extend themselves into the soil; and the earth around the stem should be left a little dishing, to gather up the water that falls. It is also desirable to fill up the pits with mould and ashes. When these conditions are properly attended to, the tree will be, not only more thrifty at first, but the influence will extend often through the whole period of life.

There are many other points on the subject of horticulture, which are important for the professional gardener; especially the management of green-house plants. But as these are of little importance to the farmer, we shall here close the subject, and with it our book, with the hope, that we may at some future period, be able to supply its present defects.

END.

INDEX.