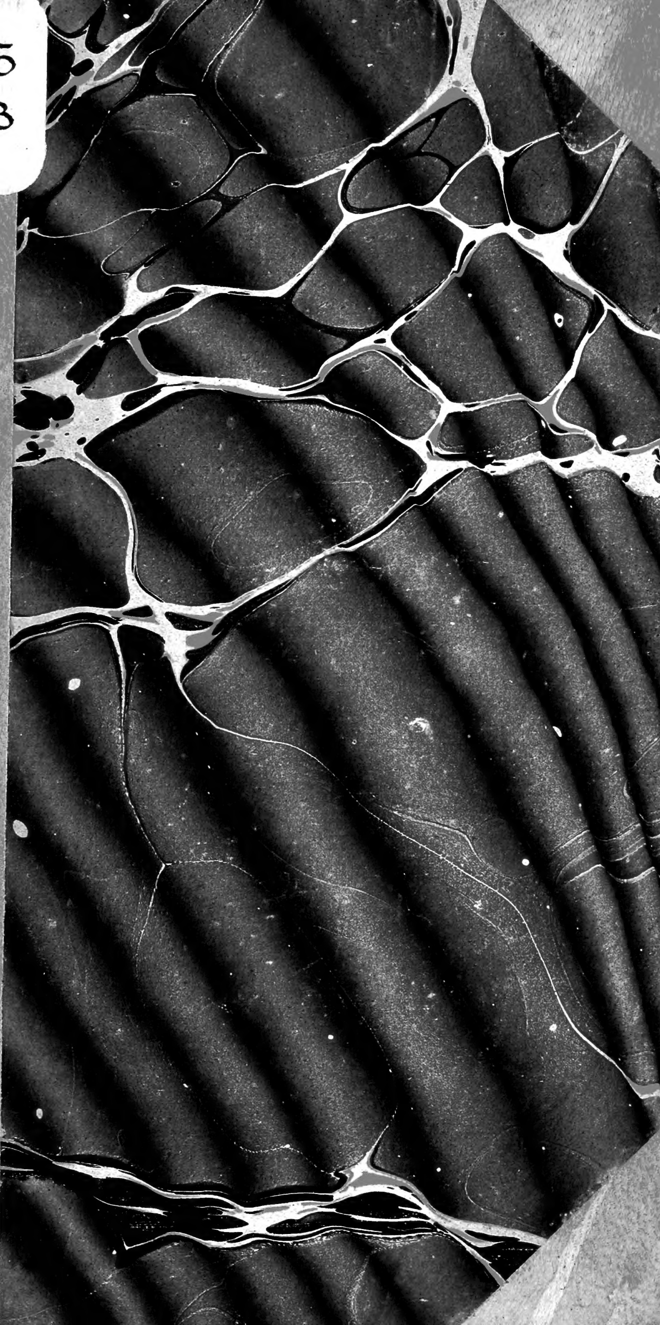

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PRODUCTIVE FARMING;

OR

A FAMILIAR DIGEST OF THE RECENT DISCOVERIES OF LIEBIG,
JOHNSTON, DAVY, AND OTHER CELEBRATED WRITERS ON
VEGETABLE CHEMISTRY; SHOWING HOW THE RESULTS
OF TILLAGE MIGHT BE GREATLY AUGMENTED.

BY JOSEPH A. SMITH.

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PRODUCTIVE FARMING.

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PREFACE.

This book is a compilation. The object of its compiler has been the simplification of the more strictly scientific and technical writings of the principal agricultural writers of the present age. Practical farmers require the simplest and most elementary statements. The position of the agricultural interest renders it desirable that the recent views of Professor Liebig, the distinguished chemist, who has effected a complete revolution in the physiology of vegetation, should be presented in a style free from difficulty, condensed and separated from such portions of his work as would only bewilder ordinary readers. How far the attempt may be successful, the world must judge. The published lectures of the late Sir Humphrey Davy have been freely cited, and such portions selected, as, while they do not clash with later discovery, may prove a useful addition. The writings of Mr. Johnston, whose little elementary book is well known, have been laid under contribution, as well as the lectures of Dr. Mason Good; and such useful statements as have appeared at various periods in periodicals devoted to the furtherance of agricultural science. It is to be hoped, that without torturing the sense of previous writers, nothing will be found in these pages inconsistent with the doctrines of the learned German professor, whose writings, though admirably adapted for the perusal of those who are familiar with chemistry and physiology, are susceptible of being abridged and presented to the industrious farmer in a form less repulsive, because less learned, and consequently, more generally intelligible.

MODERN AGRICULTURE.

CHAPTER I.

Introductory Observations.

Agricultural Science has for its objects all those changes in the arrangements of matter connected with the growth and nourishment of plants, the constitution of soils, the manner in which lands are enriched by manure, or rendered fertile by the different processes of cultivation; and no *rational* system of farming can be formed without the practical application of well-understood scientific principles. Such a system must be based on an exact acquaintance with the means of nutrition in vegetables, with the influence of soils, and the action of fertilizing materials upon them. The object of the farmer is, to raise from a given extent of land the largest quantity of the most valuable produce at the least cost, with the least permanent injury to the soil; and the sciences of chemistry and geology throw light on every step he takes, or *ought* to take, in order to effect this main object. Whoever reasons upon agriculture is obliged continually to recur to these sciences. He feels that, without such knowledge, it is scarcely possible to advance one step; and, if he be satisfied with insufficient views, it is not because he prefers them to accurate knowledge, but generally because they are more current. It has been said, and undoubtedly with great truth, that a philosopher would most probably make a very unprofitable business of farming; and this, certainly, would be the case if he were a *mere* philosopher. But there is good reason to believe, that he would be a more successful agriculturist than a person equally ignorant of farming, but ignorant of chemistry altogether: his science, as far as it went, would be useful to him. The great purpose of chemical investigation in agriculture ought, undoubtedly, to be the discovery of improved methods of cultivation; but to this end, not only practical knowledge but general scientific principles are alike necessary; nor is industry ever so efficacious as when directed by science; as he who, journeying in the night, aided by the most intelligible directions as to the way, is more certain of his footsteps if he carry a lamp to explore his path. Science cannot long be despised by any persons as the mere speculation of theorists, but must soon be considered, by all ranks of men, in its true point of view,—as the refinement of common sense, guided by experience, gradually substituting sound and rational principles for vague popular prejudices. If land be comparatively unproductive, the sure method of determining the cause is, first to ascertain the exact nature and relative quantities of the ingredients which form the soil, (which can only be done by chemical analysis,) and then to supply such soil with the deficient materials requisite for the growth of such vegetables as it is best fitted to raise. The preparation of compost will only be of real use when materials, which do not afford singly an efficient or convenient manure, are made to do so by their mixture. Every farmer has it in his power so to compound the best from his store of manuring materials, that the defects of his soil may not only be remedied, but that the crops may receive those substances in sufficient quantity which are required for their vigorous growth. To do this, however, it is requisite to know not only the component parts of the soil, but also those of the crops. If these are not taken into account, no clear idea either of the composition, much less of the action of manure, will ever be obtained; and many substances of real value will be tried, and, from misapplication, tend to useless, if not injurious results. Perhaps iron may be found in injurious excess, which may be rendered harmless by the addition of lime; or an excess of sand may be neutralized by the addition of clay. Is there a deficiency of lime? The remedy is obvious; or an excess of undecomposed vegetable matter may be removed by the judicious use of lime, by paring and burning. With the aid of chemistry, the precise value of any variety of limestone may be determined in a few minutes; and so its fitness or unfitness, as one among many substances intended to fertilize the soil, may be determined by a less expensive experiment than waiting to observe its action upon the land. In the same way, peat earth of a certain consistence and composition is an excellent manure; but there are some varieties of peat which contain so large a quantity of iron as to be absolutely injurious, if not destructive to corn and grasses. Now, nothing can be more necessary, more useful, and fortunately more simple, than the mode of determining whether a metallic substance be present. More especially, it is solely by a reference to the elementary principles of chemistry, and the ascertained constitution of manures, vegetables, and the air and soil in which they live and thrive, that we can determine whether it is wiser to plough that manure into the land, to apply it in a fresh, or in a fermented and decomposing state. We know, that soon as dung begins to decompose, it throws off its volatile or gaseous parts. It is necessary that what is thus lost should be examined. It may be (which is the fact) that such evaporation is not only the escape, but the *actual loss* of that which forms a most material ingredient in the food of plants: and so, whether this shall be supplied gradually to the growing vegetable, or suddenly, is a tantamount question in the mind of an intelligent agriculturist to the inquiry often agitated among practical farmers, and determined only by individual caprice or fancy, as to whether the produce of the stable or the farm-yard is best, when spread upon the soil in a fresh or in a putrid state. When, for instance, it is considered, that with every pound of the strongly-pungent smelling ammonia lost in the air, a loss of at least sixty pounds of corn must correspondingly be sustained,—and that with every pound of urine a pound of wheat might be produced,—not only must we feel surprise at the ignorance which prevails as to the fact, but equally so at the indifference manifested by those who are aware of the value of such manure as to the best mode of applying it. On some soils a plant will thrive, on others it will sicken; and the same knowledge which will enable us to correct a faulty or weak vegetation, will enable us also to produce far more abundant results than occur under the most favourable ordinary and natural circumstances. Agriculture has hitherto never fairly sought aid from that science which is based on the knowledge of those substances which plants extract from the soil, and of those restored to the soil on which they grow by means of manure. The application of such principles will be the task of a future generation; for what can be expected from the present, which recoils with seeming distrust and aversion from all the means of assistance offered by chemical investigation? A future generation will derive incalculable advantage from these means of help, and make a rational use of philosophical discoveries. Here a marked and wide difference exists between the progress of manufacture and the history of agricultural operations. We see the steam-engine multiply indefinitely the labour of the human hand—supersede and almost infinitely exceed the united power of brute exertion; invention has lacked no mechanism to produce myriads upon myriads of the same fabric; thousands of piles of manufactured silks and cottons are produced annually, one factory supplying daily as many yards as would encircle the globe—strange advancement on the ancient spinning-wheel; while the sons of the soil still toil on through the long summer months, and brave the winter's cold, to reap the same quantity of produce from the soil as their forefathers of a thousand years ago. We do not say that there is no limit to the capabilities of the earth's surface, but fearlessly maintain that such limit is yet far from realization; and that not until prejudice be silent, and intelligence more universal, can it be hoped that the broad acres of our island home will yield to science and skill all the treasures they contain.

At a recent meeting of one of the Irish agricultural associations, a Scottish agriculturist is reported to have said, among other things, that "If science were permitted to do for farming all of which science is capable, the clamour about repeal of the Corn Laws would soon cease, and the prospect of starvation before us would vanish." He observed, that "Great Britain, besides supplying her own population with food in abundance, would become an exporting country for ages to come: that unless a more rational system of farming be adopted throughout the country, we shall have want, and its offspring, crime, at our doors and on every side of us. The manufacturers are offering premiums on the increase of population. That population is increasing far beyond the supply of food necessary for it, [he might have added, at the rate of a thousand a day, while the surface of our island remains the same;] and unless the government, or the great agricultural societies, take the matter in hand, and that speedily, we shall soon feel that, solely from *lack of food for her* MANUFACTURING population, the greatness of this empire, so long the wonder and envy of the world, will become a thing to be talked of as a tale that has passed away."

Half a century sufficed to Europeans, not only to equal, but to surpass the Chinese in the arts and manufactures; and this was owing merely to the application of correct principles deduced from the study of chemistry. But how infinitely inferior is the agriculture of Europe, even of boasted England, to that of China! The Chinese are the most admirable gardeners and trainers of plants, for each of which they understand how to prepare and apply the best adapted manure. Their agriculture is the most perfect in the world: and there, where the climate in the most fertile districts differs little from the European, very little value is attached to the excrements of animals. Patient observation of results, and a ready adoption of really useful plans; steady persistence, not in antiquated methods and notions, but in all that has been found by experience to be beneficial,—has raised the agriculture of that country, long ago, to a position which would rapidly, nay, instantly, be ours, if science were permitted to achieve for us that which, with them, has been the slow growth of centuries of experiment.

The soil of England offers inexhaustible resources, which, when properly appreciated and employed, must increase our wealth, our population, and our physical strength. The same energy of character, the same extent of resources which have always distinguished Englishmen, and made them excel in arms, commerce and learning, only require to be strongly directed to agriculture, to ensure the happiest effects. We possess advantages in the use of machinery and the division of labour, peculiar to ourselves; and these having been mainly instrumental in aiding one great division of human industry, we are justified in the assertion, that the steam-engine and machinery has not done more for trade, than science and skill, in various ways, may do for land. Although it is obvious to all reflecting persons, that machinery, which is science in another form, is a good thing, we cannot wonder if we find some ready to say, "I know it is a bad thing, for it deprived me of employment." To attempt to convince such a man would be difficult. It would be useless to argue with that man, that a number of individuals had gained, though he was a loser. His loss is to him evident; and the gain spread over a vast surface of society is an argument which makes no impression upon him.

Besides chemistry, there is another science which has many relations to practical farming—the science of geology, or that which embodies all ascertained facts in regard to the nature and internal structure, both physical and chemical, of the solid surface of our globe. Though the substances of which soils *chiefly* consist are so few in number, yet every practical man knows how very diversified they are in character, how very different in value. Thus, in some of the southern English counties we have a white soil, consisting, apparently, of little more than chalk; in the central part of the country, a wide plain of dark-red land; in the border counties of Wales, and on many of our coal fields, tracts of country almost perfectly black; while yellow, white and brown lands give the prevailing character to the soils of other districts. These differences arise from the varying proportions in which the sand, lime, clay, and iron which colour the soils have been mixed together. Now, geology explains the cause why they have been so mixed in different parts of the country—by what natural agency, and for what end; and by its aid we can predict the general quality of the surface-soil, and, more than this, of the unseen *sub-soil* in the several parts of entire kingdoms. We may learn, if the soil be of inferior quality, and yet susceptible of improvement, whether the means of improving it are likely, in any given locality, to be attainable at a reasonable cost.

Whether we attempt to investigate the composition of natural bodies, or, confining our attention to the review of those general diversities so remarkable on the earth's surface, the division of them all into two grand classes, as simple or compound, is an essential preliminary to a correct comprehension of the subject. Those substances are *simple*, which cannot, by any known method, be separated, decomposed, or divided, in such a manner as to produce particles different in their properties from one another. On the other hand, those substances are *compound* which, by experiment, may be resolved into particles of an unlike nature. Thus, marble is a compound body; for by a strong heat it is converted into lime—an elastic fluid, which is carbonic acid gas, (itself also a compound,) being disengaged during the process. Vegetable substances, whether in their living or dead state, are mostly of a very compound nature, and consist of a great number of elements. For a period of many centuries, and even till a very late date, there were four substances held to be elementary, or simple. These were Fire, Air, Earth, and Water. Nobody could prove them so; and yet, of these four bodies, all others in nature were supposed to be constituted. This system continued to be orthodox till very lately, when *three* of these imaginary elements, namely, Air, Water, and Earth, were proved to be compounds; and, as we shall see in the progress of this work, a correct understanding of the properties of the atmosphere, and of its relative agency over vegetation, is indispensable to the adoption of such plans as are intended to increase the fertility of the soil. As to fire, it is still unknown whether it be simple or compound, in what its essence consists, or by what causes its effects are produced. The study of temperature, of the relative dryness or moisture of the air, of the action of the sun's heat over soils and vegetation, is closely identified with the science of agriculture. The influence of the changes of seasons and of the position of the sun on the phenomena of vegetation, demonstrates the effects of heat on the functions of plants. The matter absorbed from the soil can only enter the roots in a fluid state; and when the surface is frozen, this mode of communication is suspended. The activity of chemical changes in living vegetables is likewise increased by a certain increase of temperature, as is evident if a stalk of henbane be partially immersed in hot water: its leaves will, for a time, become erect, and quickly forego their drooping arrangement, evidently referable to the increased rapidity with which fluids, under such circumstances, rise in the minute vessels of the vegetable. Heat, then, is rather to be regarded as an agency by which both compound and simple substances are alike affected. What the ancients considered to be *simple* bodies, are no longer considered to be such: but, in place of these four assumed substances, the chemists of modern times have elevated to the dignity of elements, or *simple* bodies, a far more numerous race. No one, however, asserts now-a-days, that even these are all absolutely simple. The term "element," intimates no more than that the body to which it is applied has never, in the opinion of modern chemists, been subject to further division or decomposition: that it has never been divided into particles, different from one another, or from the original substance. The number of simple, or elementary substances, at present known, and constituting visible Nature around us, is *fifty-four.*

Now, if these elementary, or simple substances are placed either artificially, or, as they are presented in the universe, naturally in contact with each other, they combine, or refuse to combine ; and by such combination, when it occurs, a great variety of *compound* substances are produced. Some combinations are effected instantly, some more slowly and with difficulty, and there are certain elements which can scarcely, by any means, be made to combine. The compounds produced by such combinations possess properties very different from those of the separate elements of which they are composed. Thus, carbonic acid, or the gas which sparkles in fermented liquors, combines very readily with pure caustic lime, and the product of the union is common chalk. So, if the proportions be varied, the same two elements produce the common air we breathe and the strongest aquafortis or nitric acid. The *power,* in virtue of which simple bodies can combine and produce compounds, is one of which the nature is totally unknown. Chemists have learned no more than that simple bodies, or bodies supposed to be simple, *do combine ;* but WHY they combine, or what that is which makes them combine, they have not discovered. To the illustrious Dalton belongs the discovery that they do not unite at random, but always in definite proportions of each ; so that, if the elements be represented by numbers, the proportions in which they unite may be expressed either by those numbers, or by some simple multiples of them. Thus, sugar and Indian rubber are compounds resolvable into precisely the same *ultimate* elements, only in different proportions ; and, as the following table will illustrate, nearly one half the weight of all vegetable productions which are gathered for food for man or beast, in their dry state, are but varying compounds of the same elementary or simple bodies, the names of which are appended over the annexed numbers. What the properties of these elements in their separate state may be, is not our immediate purpose.

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
Hay, ...	458	50	387	15	90
Potatoes, . .	441	58	439	12	50
Wheat straw,	485	52	389	4	70
Oats, ...	507	64	367	22	40

parts by weight in 1000 pounds of each of the above vegetable substances.

If we take the ash left by a known weight of wheat straw, or of hay, and mix it with the proper quantities of the four elementary substances named in the foregoing table, we shall certainly be unable, by this process, to form either the one or the other. The elements, therefore, into which all vegetable compounds are ultimately resolvable, are not merely *mixed* together; they are united in some closer and more intimate manner. To this more intimate state of union the term *chemical combination* is correctly applied. Again, woody fibre, gum, sap, and the various fluids and substances which form a plant, are themselves mostly resolvable into varying proportions of the same ultimate elements, which, taken together form the entire vegetable. Thus, sugar forms one of the *proximate* principles of the sugar cane, and India rubber is one of the *proximate* principles of a South American tree, which contains no sugar; yet sugar and India rubber are *essentially* composed of the same materials. So, if charcoal be burned in the open air, it slowly disappears, and forms a kind of air or gas, known by the name of carbonic acid, an elastic fluid precisely identical with that which forms the froth in ginger beer or common yeast. Now, this carbonic acid is formed by the union of the charcoal or carbon, while burning, with one of the elements composing common air, named oxygen; and in this new form, the elements carbon and oxygen are said to be *chemically combined.* Again, if certain vegetable and animal materials are mixed together, and left to the agency of the atmosphere, they react upon each other—perhaps become heated, as happens in a heap of stable dung, and are said to become *decomposed.* New compounds are formed from the union of previously existing elements; perhaps AMMONIA is one of the most common and obvious, as indicated by its effect upon our eyes and nostrils. This, then, is as purely a chemical process as the conversion of wood into vinegar, or into charcoal, or the change that occurs when the flour of grain is converted by the distiller into ardent spirits; and in all well-directed attempts to fertilize the soil, a knowledge of these changes is absolutely necessary: at least, he who proceeds without it has disappointment in prospect, and gropes in the dark, with uncertainty for his guide.

Now, *chemical affinity* is not only evident in the changes which masses of dead inorganic matter produce upon each other: it is found to be actively at work in the phenomena of vegetation; thus proving that the growth of plants is more completely a chemical process than might have been imagined: and, as our further illustrations will tend to prove, the same law of affinity is equally operative upon *animal* structure, which, like that of plants, is not more truly *alive* than they. The sap consists of a number of ingredients dissolved in water by chemical attraction; and it appears to be in consequence of the operation of this power, that certain principles derived from the sap are united to the vegetable organs. By the laws of chemical attraction, different products of vegetation are changed and formed during the process of growth: vegetable and animal remains are decomposed by the action of air and water, or exert upon those fluids a mutual agency essential to the change; rocks are broken down and converted into soils, and soils are more finely divided and fitted as receptacles for the roots of plants. The repulsive energy of solar heat, or of that generated during chemical changes of constant occurrence, serves as the only counterbalance to that *attraction* which pervades the particles of all living or dead matter: and thus the harmonious circle of growth and decay is produced by their mutual operations. The different influence of the different solar rays on vegetation is but partially understood. There are rays transmitted from the sun which do not impart light, and which yet produce more heat than the visible rays. The effect of these invisible rays is purely *chemical* and independent of the heat they produce. Thus, potatoes, which sprout in a comparatively dark cellar, send out nearly colourless shoots. Plants kept in the dark in a hot-house, grow luxuriantly, but never acquire their natural colours; their leaves are white or pale, and their juices watery and sweet. So the upper surface of most leaves is darker than the lower, upon the same principle that the belly of a fish is whiter than its back.

The most obvious instance of *Electrical Agency* in external nature occurs in thunder and lightning. Electrical changes are of constant occurrence; but as yet the effects of this power, not as accidental, but as essential to healthy vegetation, have not been correctly estimated. No doubt the germination of seeds, as well as the growth of plants, is materially modified by the peculiar electrical condition of the earth and the atmosphere, and by the varying state of each. It is known that corn will sprout more rapidly and readily in water positively electrified—that is, charged with electricity in excess or beyond its natural quantity; and that if, by artificial means, water be deprived of its natural amount of electricity, its power of stimulating the growth of seeds is thereby diminished. Experiments made upon the atmosphere show that clouds are usually deficient of electricity; and as when a cloud is in one state of electricity, the surface of the earth beneath that cloud is brought into the opposite state, it is probable that, in common cases, the surface of the earth is charged with the electric fluid in excess.

We have spoken of Chemical *affinity:* it is sometimes well named *Elective* or Chemical attraction, in as much as it is but an exemplification of one form of that law which maintains the order of the universe. It is the expression of the fact, that certain elements of unlike nature combine with each other when placed in contact, or (figuratively speaking) refuse to combine with any other, electing even the proportions in which only such combinations can occur. This affinity is but one division of the great law of *attraction.* In this aspect, there are *five* forms in which the relations of all bodies to each other may be arranged. We begin with that which compels the heavenly bodies to rotate round the sun; or a stone when thrown upwards to fall to the ground—in other words, to *gravitate* towards the earth's centre. Next, there is the *attraction* of cohesion: thus, particles of oil will rise through water, and having reached the range of each other's attraction, will unite into one common and separate body. It is this form of attraction which gives roundness to the drops of dew, or of the rain as it falls, and is the sole cause of the arched form of the rainbow. In the same way, drops of water or of quicksilver placed upon a dry plate, have a tendency to unite, not only when they touch, but to run together when placed near each other. So, perfectly smooth and polished plates of glass or metal have a strong tendency to cohere. It is by the same means that the great number of rocks seem to be produced that enter into the substance of the earth's solid crust. The lowermost rocks are united by an intimate crystallization which is the most perfect form of cohesive or aggregate attraction that can exist among the particles of solid bodies. The next form of *attraction* is observed as occurring between bodies *unlike* in their nature, solids and fluids, *capillary* attraction, as when sap rises in the minute vessels forming the stem of a tree against its own weight, or in other language, overcoming the attraction of gravitation downwards. The Latin word which signifies a hair, is used in this instance to form the word denoting the extreme tenuity and delicacy of these narrow vessels, as only in such could fluids rise: hence the reason and the wisdom of this arrangement.

Electrical and Magnetic attraction are important subjects for study, to which in a practical work it is not necessary very minutely to allude. It is well ascertained that the thorns, spines, or prickles that exist on a variety of plants serve not merely for their defence; they have a relation to the electrical condition of the atmosphere; cases having been recorded in which spines have grown more than an inch during a thunder-storm. Some of the acacia tribe are fretted over with formidable spines which will take off a charge of electricity from a prime conductor as rapidly as a brass point—doubtlessly from the presence of a metal in those spines, probably the metallic base of flint. Now it is very unlikely that only the prickly plants require the electric stimulus. We know that, though the torpedo and electrical eel have power to benumb and kill, yet human beings, who have no such powers in health and in disease, are always charged with varying quantities of the electric fluid. So also of all vegetables: oat and wheat straw contain silica, which is metallic; and the firmness of the stem may not be, and is not, the only reason for its presence. Lastly, we have *Chemical attraction* or *affinity*. A few instances of its operation have been already noted; but some affinities are more powerful than others. Pure lime has a strong affinity for carbonic acid gas, and this is a wise ordination; and it is equally a proof of design that it should form one of the ingredients of the atmosphere. Under this arrangement of things, whole mountains of lime have been crumbled during successive ages into fertile beds of chalk. But lime has a still greater affinity for sulphuric acid or oil of vitriol than it has for carbonic acid; and so, if natural or artificial chalk be subjected to the action of vitriol, another decomposition ensues: the carbonic acid flies off, leaving the lime to combine with the acid for which it has a more powerful affinity, the result of the new union being sulphate of lime, better known as *alabaster* or *common gypsum*. These transformations may not only be produced artificially, but are of constant occurrence, though of slow operation, in the great laboratory of Nature. To understand them is essential to the slightest knowledge of those chemical changes which are identical with the processes of growth in the vegetable world, and indeed in all living organized bodies,—and there are sufficient motives connected both with pleasure and profit to encourage ingenious men to pursue this new path of investigation.

CHAPTER II.

Some Account of the Simple or Elementary Bodies found (combined or uncombined) in Animals, Plants, and Soils.

It is absolutely necessary, in order to a right apprehension of the changes that occur during vegetable growth, and, of course, to a correct estimation of the most rational methods of forcing or favouring healthy vegetation, that we should become familiar with some of the most common properties of those simple bodies or elements, of which all nature around us is compounded.

Four of them, by combining with other simple bodies that will burn, form acids; eight of them are inflammable; and there are upwards of forty metals.

First, let us speak of *Oxygen*. Oxygen, in union with latent heat, forms Oxygen gas, constituting about one-fifth of the air of our atmosphere. It is an elastic fluid at all known temperatures. It is heavier than the air, and supports combustion with much more vividness than common air; so that if a small steel wire, or a watch spring, having a bit of burning wood attached to it,—or, better still, a bit of phosphorus or brimstone, be introduced into a bottle filled with this gas, it burns with surprising splendour. Oxygen is a substance very extensively diffused throughout the material world: it forms with nitrogen the air we breathe; united with another element, named hydrogen, it forms water. It exists as a constituent of all animal and vegetable matter; and is found also naturally in combination with most mineral productions; from some of which, for experimental purposes, it may with great ease be prepared. Oxygen gas, when suddenly compressed, evolves both light and heat; is sparingly dissolved by water, 100 cubic inches taking up only three or four of the gas. If a mouse, or a bird, were confined under a large bell-glass, filled with common air, it would live until it had consumed all the oxygen contained in that portion of air, and no longer. If, instead of the bird, a bit of burning brimstone, or a candle were placed there, it would burn until it had absorbed all the oxygen, and then become extinguished.

2. *Hydrogen.*—Hydrogen, or inflammable air, is the lightest known substance, being about sixteen times lighter than common air. For this reason, it is used in filling balloons. The common gas in the streets and shops is mostly used for this purpose, instead of pure hydrogen; the carbon it contains not materially destroying its lightness. Not only is pure hydrogen the lightest of gases, but it is highly inflammable; it will neither support combustion nor respiration; in other words, if a lighted taper or a living animal be immersed in pure hydrogen gas, it would cease to burn, or die. Hydrogen and oxygen are the two elements which form pure water, of which we must say more in another place. When these gases are mixed in certain proportions, they unite and explode with great violence if a lighted candle be brought in contact with them; for experiment' sake, one part of hydrogen, and six of oxygen or even atmospheric air, will form a very powerful explosive mixture. When a stream of hydrogen gas issuing from one vessel, and a jet of oxygen from another, are made to inflame as they unite, a most intense heat will be generated, sufficient to melt the clay of a common tobacco pipe, and render lime perfectly fluid. Neither hydrogen nor oxygen are known to occur anywhere in nature in any sensible *separate* quantity. They are abundant enough in combination with other matters.

3. *Nitrogen*, sometimes called Azote, is another elementary substance, entering most largely into the constitu-

tion of universal nature. United with the matter of heat, it may be artificially produced and presented as a transparent, colourless, insipid, incombustible gas, incapable of supporting flame or breathing. It may be made to unite with oxygen (but of course only in certain definite proportions) by the agency of electrical fire. It may easily be procured by burning a bit of phosphorus in a confined portion of air over water. The inflamed phosphorus rapidly unites with the oxygen until it has exhausted all that the air contains, then combustion stops, and the remaining gas is nearly pure nitrogen. Small creatures soon die in it for want of oxygen. It *combines* in five different proportions with oxygen, forming, in one instance, nitric acid or aquafortis; and *mixed*, rather than chemically combined, with one-fifth its bulk of oxygen, it forms the air we breathe. Though ammonia is not a simple body, and, therefore, not to be classed with the present list, it may not be inappropriate, after the mention of hydrogen and nitrogen, to say that it results from the union of the two. Ammonia exists in rain water, and, as we shall subsequently show, is an important auxiliary to vegetable growth; it becomes developed in putrid urine or stable compost; it is a colourless gas, with a strong pungent odour. It dissolves easily in water, and is then called hartshorn. It is very volatile; has all the common properties of soda and potash, combining readily with acids. Sulphate of ammonia exists largely in the soot from coals. From this source the "sal ammoniac" of commerce is procured.

Carbon.—Charcoal is the most usual, and best known variety of carbon. It is black, soils the fingers, and is more or less porous, according to the kind of wood from which it has been formed. Coke, obtained by charring, or distilling coal, is another variety. It is generally heavier or denser than the former, though less pure. Black-lead, or carburet of iron, there being in reality no lead in its composition, is a third variety, still heavier and more impure. The diamond is the only form in which carbon occurs in nature in a state of perfect purity. That the diamond is essentially the same substance with pure lamp-black is a very remarkable circumstance. Charcoal, the diamond, lamp-black, and all the other forms of carbon, burn away more or less slowly when heated in the air; and, combining with the oxygen of the atmosphere, form carbonic acid.

Oxygen, hydrogen, nitrogen, and carbon, form the ultimate elements into which all the *organized* part of all vegetable and animal substances is resolvable. We say *organized:* bones contain lime, and vegetables contain earthy and saline matters; but these are *not* organized, they are deposited in cells, or in a structure so arranged as to contain them.

Chlorine, or Oxymuriatic gas, is, like oxygen gas, a permanently elastic fluid. When pure, it has a greenish yellow colour, and a very disagreeable odour and acid taste. It may not be breathed, and burning bodies are extinguished by it. It destroys all vegetable and animal colouring substances, as also the effluvium arising from the putrefaction of dead animal matter. It does not exist separately in nature, but is one of the components of common salt.

Fluorine.—This substance has such strong tendencies to combination, that as yet no vessels have been found capable of containing it in its pure form. It is one of the elements composing the Derbyshire fluor spar or blue john. This mineral is a fluate of lime, in other words, a compound of fluoric acid and lime. Now, fluoric acid is itself a compound of fluorine and hydrogen; and lime is not a simple body, but in reality the oxide or rust of a metal named Calcium, from the latin word "Calx," signifying lime. Fluoric acid may be obtained from the Derbyshire spar by the action of sulphuric acid, which combines with the lime in consequence of the greater affinity of the two than exists between lime and fluoric acid, which by such process may be separated.

Having disposed of these, we proceed to notice (not the whole range) but a few other simple substances found in nature, and chiefly in the animal, vegetable, and mineral world.

Sulphur.—This is a solid substance, of a light yellow colour, brittle and tasteless, and when rubbed, emitting a peculiar odour. Melted and poured into cylindrical moulds it forms the roll brimstone of commerce. It burns with a pale blue flame in the open air, during which process it combines with the oxygen of the atmosphere, and forms sulphuric acid or oil of vitriol. Sulphur is found native in Sicily, Italy, and Iceland, and in combination with metals and earths in greater or less quantity throughout the mineral kingdom. It is a constituent of many vegetable and nearly all animal structure.

Phosphorus.—Phosphorus is most easily obtained by burning bones to whiteness in an open fire. In this way the animal matter is driven off and nearly pure *phosphate of lime* (or a salt composed of phosphoric acid and lime) remains. This phosphate of lime, reduced to powder, is next mixed with oil of vitriol and water; decomposition ensues in consequence of the greater affinity which oil of vitriol or sulphuric acid has for lime than the phosphoric acid already in combination with it. Next, by evaporation, the addition of powdered charcoal, and exposure of the mixed mass to distillation, the liberated phosphorus is separated into its two elements, (phosphorus and oxygen,) the former of which distils over, and at a low temperature becomes solid. Phosphorus may also be prepared from urine. It takes fire at a heat considerably lower than that of boiling water. Phosphorus has a waxy consistence; when burned in oxygen gas, a very dazzling light is produced; and the result of the combination is phosphoric acid, just as sulphur or brimstone, burnt in oxygen gas, produces sulphuric acid. Phosphoric acid combined with lime, forms phosphate of lime, the solid inorganic constituent of bones. Phosphate of lime is easily obtained by exposing bones to a red heat in an open fire. Its first action is to blacken the bones, converting its animal carbonaceous matter into charcoal: if the heat be continued, the charcoal or carbon unites with the oxygen of the atmosphere in the form of carbonic acid gas, and the phosphate of lime remains beautifully white, left in the shape and arrangement of the organized cells it lately filled. Phosphate of lime is found as a native mineral production in some parts of Ireland and elsewhere. Phosphorus will dissolve in spirit of wine or in oil, but is insoluble in water, under which fluid it is always preserved.

Iodine.—This simple substance is found existing as an undecompounded element in the ashes of marine plants after the extraction of the soda they contain. Sea-weed is largely used on the coasts of England and Scotland as a manure. Iodine is a dark-coloured solid, having somewhat the appearance of black-lead. It unites to all the metals upon which its action has been examined, and combines with oxygen, forming an acid.

Next, let us allude to earths and metals, or such forms of them as fall within the range of simple elementary bodies. We have already said that lime, ordinarily considered as an earth, is in reality a metallic oxide; pure soda, pure potash, calcined magnesia, pipe-clay, the base of flint, and some other similar substances, are, in truth, *metals*, united to oxygen in the same way as rust of iron is a compound of iron and oxygen. Lime, then, or, in chemical language, "oxide of calcium," combined with various acids, is a very abundant natural production, found widely diffused over every part of the habitable globe, as limestone, marble, chalk, fluor spar, plaster of Paris, gypsum, or alabaster; these, under various names, being all of them compounds of lime with the carbonic, fluoric, or sulphuric acids. Besides these, lime, in combination with phosphoric acid, enters very largely into the composition of the solid skeleton or shell of animals. Pure lime is more soluble in cold than in hot water, a fact not without its interest nor intention. If chalk be exposed to a red heat, the carbonic acid, one of its constituents, is expelled, and pure lime remains. Pure, or caustic quicklime corrodes animal and vegetable substances, and is never found in them in an unmixed state. Lime is one of the most infusible bodies known, but may be made to melt by the joint action of the combustion of oxygen and hydrogen gases. Lime has a powerful affinity for water, and the combination is attended with the extrication of great heat, as when lime is slaked for the builder. In this process the water becomes solid, *unites*, not mixes, with the lime, and in passing from the fluid to the solid state, gives out the *latent* heat necessary to maintain fluidity. This heat becoming suddenly sensible, is sufficient to carry off a portion of the water in vapour, the union of the lime and the water producing a dry solid. The same chemical union occurs when plaster of Paris, or dry sulphate of lime, is mixed in certain proportions with water: the fluid solidifies, and unites with the lime into the hard substance which forms the common plaster images or casts hawked about the streets by the Italians. Lime combines freely with many acids, existing in this form as "muriate of lime" in the water of the ocean. Of the application of earthy minerals to the land, we will speak in its proper place.

Sodium.—This is the metallic base of common table or rock salt, which is a compound of two elements, chlorine, already alluded to, and sodium, with water. The metal sodium has a lustre and colour very similar to silver, and is so soft as to be pressed into leaves between the fingers. It may be obtained through the agency of the galvanic apparatus. When thrown upon water it decomposes that fluid, it soon becomes oxidized, or robs the water of oxygen, setting its other constituent, hydrogen, at liberty, the action being accompanied with a hissing noise. Chloride of sodium, or common salt, is abundantly diffused over the world, both as a solid mineral production, and as the principal ingredient in sea-water; it is essential to healthy action, as well in vegetable as in animal nutrition. If thrown upon hot coals, salt crackles, because the water it contains is not chemically combined, but merely mixed or interposed between its particles, and so expanding by heat causes the separation of those particles and the resulting sound. Sodium united to oxygen, forms pure soda; pure soda united to sulphuric acid, forms the Glauber salt, so commonly given to cattle; pure soda united to carbonic acid, forms the substance sold in the shops as "soda," and bought for the purposes of the washerwoman.

Potassium.—This is the metallic base of common pearl ashes. If the pure metal be thrown upon water, like sodium it swims on the surface, and darts violently hither and thither, with the sudden extrication of flame. This flame is burning hydrogen, and the phenomenon arises from the great affinity of potassium for oxygen, abstracting it from water, or all bodies that contain it. If the metal potassium be united with oxygen, it forms pure, or caustic potash, or oxide of potassium; if pure potash be united with carbonic acid, the result is carbonate of potash, of which *pearl ashes* is an impure variety. United with nitric acid, potash forms saltpetre, which is found very abundantly as a natural product. Potash, combined with oxalic acid, is found in sorrel, and other sour plants. Impure carbonate of potash remains in the ashes of most vegetables, and so largely in some of them, as to yield the immense supply for trade. Potash, united with fatty or oily substances, forms the various kinds of soap.

Silicon is another metal which, in union with oxygen, forms *silica*, or siliceous earth, existing native in great abundance, and forming the chief ingredient in *flint*, quartz, and rock-crystal. From these substances silica may easily be obtained, by first heating them to redness, and then throwing them into water. For all common purposes, sand from the glass-house will answer. It unites with potash, and forms glass, and is insoluble in all acids, except the fluoric acid, for which reason this acid is kept in leaden bottles. Silica exists very largely in the hard coating of the sugar cane. In the stem of wheat straw, silica is essential to the firm, erect position of the plant; consequently, if the soil be deficient of silica, (a fact which is easily determined,) the ear of corn will droop, upon a slender, short, and lanky straw.

Aluminium.—This metal, in combination with ogygen, forms pure alumina. Alumina, more or less pure, exists as a most abundant natural production, being found as a chief constituent of *clay*, for pottery and bricks. Crystallized, it forms those precious gems, the ruby and sapphire: so that the difference between a bit of charcoal and a diamond, is a similar difference to that which exists between a bit of clay and a precious jewel—merely a diversity in the arrangement of particles of the same matter.

Barium.—A metal forming the base of the earth baryta, and of the various acids in combination with that earth. Carbonate of baryta is found native in Derbyshire. Pure baryta, like lime, slakes when in contact with water; for which it has so strong an affinity, that the heat of a forge will not drive it off.

Magnesium.—The metallic base of the earth magnesia, the calcined magnesia of the shops. In combination with muriatic acid, it exists largely in sea-water. With sulphuric acid, magnesia forms the common Epsom salt, and is found as a native magnesian limestone, in combination with lime and carbonic acid.

Iron.—Iron is found native in many parts of the world, and is also very abundant in combination with sulphur, and many other substances, such as oxygen, forming oxides; also in further union with acids, forming carbonates, sulphates, and phosphates. Green copperas is a sulphate of iron. Rust of iron, produced by the action of the atmosphere, arises from the combination of the iron with oxygen, derived from the air, and also with a portion of carbonic acid from the same source, and so may be correctly named carbonate of iron.

Lead.—Metallic lead is rarely found native, but is obtained in large quantities by smelting the sulphuret, a mineral known by the name of galena. Lead is found also in combination with oxygen and acids.

Copper.—This metal occurs very commonly native in a state of perfect purity, sometimes in large masses, at other times in a crystalline form. It is commonly found in combination with sulphur, from which it is generally obtained. Blue stone, used by the farrier, is a sulphate of copper.

Zinc.—Metallic zinc, sometimes named spelter, is obtained either from the impure carbonate, a native production called "calamine," or from another natural compound, the "sulphuret," or zinc blende. White vitriol used in veterinary medicine, is a sulphate of zinc. The ores from which it is smelted, exist largely in some districts.—Tin, bismuth, antimony, arsenic, nickel, cobalt, and many other metallic substances, might similarly be enumerated; but these, existing in comparatively minute quantities, may be safely passed over. The elements found in vegetables are but few. Oxygen, hydrogen, and carbon, form the greatest part of their organized matter. Nitrogen, phosphorus, sulphur, manganesum, iron, silicum, calcium, aluminum, and magnesium, enter into their composition, or are found in the agents to which they are exposed; and these *twelve*, out of nearly sixty *undecompounded elements*, require to be familiarly understood by the agricultural chemist. Life gives a peculiar character to all its productions: the power of attraction and repulsion, combination and decomposition, are subservient to it. A few elements, by the diversity of their arrangement, are made to form the most different substances; and similar substances are produced from compounds which, when superficially examined, appear entirely different.

CHAPTER III.

Plants and **Animals** are both alike endowed with **Life**; the *Elementary Materials* and many of the *Proximate Principles* of *Animal* and *Vegetable matter are precisely identical*—they have *similar* **Organs** essential to their *growth* and *reproduction*, and are *nourished* or *destroyed* by the same agencies.

If I dig up a stone and remove it from one place to another, the stone will suffer no alteration by the change of place; but if I dig up a plant, and remove it, strip its leaves, and leave the stem standing, or mutilate an animal, —that plant or animal will instantly sicken, and perhaps die. What is the reason of this? Both have been perfected in connexion with the same common soil. If I break the stone to pieces, though chemically, it may consist of several elements, yet every individual fragment will be found possessed of the original character of the whole mass; it is only altered in shape and magnitude; but if I tear off a branch from a plant, it will wither and lose the properties of its parent stock. The mineral can only be destroyed or changed by mechanical or chemical force; while the plant, like all animals, has been produced by generation, has grown by nutrition, and been destroyed by death,—in fact, it has been actuated by an internal power.

In what this internal power consists, we know not. Differently modified, we meet with it in both plants and animals. Wherever we find it, we denominate it the "PRINCIPLE OF LIFE;" its presence forming a clear distinction and boundary between the two great families of animals and plants, and all else besides in the universe. A cabbage is not less truly alive than the ox which feeds upon it. The superiority of the animal over the plant consists chiefly in this—the existence of mind or intellect; and correspondingly, a brain and nerves, of which the plant is deficient.

Now, all living things are said to be *organized;* that is, made up of *various structures*, evidently destined to answer certain ends; and these, taken together, compose the entire plant or animal: as the root, sap vessels, bark, leaves, and other organs of a tree; and correspondingly, the bones, muscles, blood-vessels, skin, and lungs of a horse, a man, or of a sheep. But this description is not true of a piece of limestone, or a lump of clay, and, therefore, it is said to be *inorganized.* Hence, all the various bodies in nature arrange themselves naturally under the two great divisions of organized and vital, or inorganized and dead, without a single exception.

In their more perfect forms, the distinctions between animal and vegetable life are obvious enough. There is a wide distinction between a horse chestnut and a chestnut horse; but as we approach the contiguous extremities of the animal and vegetable kingdoms, the distinction is not so easy. There are some natural productions which have been originally considered as minerals, afterwards as vegetables, and have at last been regarded as belonging to the animal kingdom; less on account of any other property they possess than their similarity of chemical and elementary constitution to the well-known ingredients of animal matter. Sponges, and many fungous growths, are of this character.

In what part of a plant the living principle chiefly exists, or to what quarter it retires during the winter, we know not; but *we are just as ignorant in relation to animal life.* In both, it operates towards every point; it consists in the whole, and resides in the whole; and its proof of existence is drawn from its resisting those putrefactive or chemical agencies which instantly begin to operate as soon as the plant or animal is dead. While life exists, a vegetable or animal thrives and increases in its bulk; a tree puts forth annually a new progeny of buds, and becomes clothed with a beautiful foliage of lungs, (every leaf being in itself a distinct lung,) for the respiration of the rising brood, and with an harmonious circle of action that can never be too much admired, a perpetual supply of nourishment is furnished first for its own growth, next for the growth and perfection of animal life; while, from its own decay, as well as from the death of animal matter, there is formed, in rich abundance, the means of new births, new buds, and new harvests. In fact, every thing is formed for every thing, and subsists, (if we may speak figuratively) by the kind intercourse of giving and receiving benefits. Such is the simple, but beautiful, circle of nature. That which lives, flourishes, decays, and dies, is not lost; the great principle of life only changes its form; and the destruction of one generation of plants or animals is but the necessary requisite to the support or existence of the next.

CARBONIC ACID, AMMONIA, and WATER, yield elements out of which are built up all the *organized* parts of plants; and it is no less true that these elements form the entire *organized* structure of animals. This being the fact, we should naturally suppose the conditions essential to the growth of each are the same; in fact, that the food consumed by vegetables and animals would prove essentially similar: and *such is actually the case.* The process of digestion in an animal is precisely identical with the process of appropriation or nourishment in a plant. Certain *inorganic* substances, salts and metallic oxides, serve peculiar uses, as lime to give solidity to the bones of an ox; and silica, or the earth of flints, to serve the same end in wheat straw.

We have already spoken of the *elementary* or *ultimate* constituents of vegetables. Out of these are formed the various *immediate* compounds which are found in them The compound substances found in vegetables are,—1. Albumen; 2. Gum; 3. Sugar; 4. Gluten; 5. Woody fibre; 6. Starch; 7. Extractive; 8. Tannin; 9. Resin; 10. Wax; 11. Fixed and volatile oils; 12. Bitter principle; 13. Free acids; and a few others; to which must be added the mineral, saline, or metallic substances they contain.

Out of the same elementary constituents of vegetable and animal structure are formed the materials composing the blood and all the secretions—fibrin, gelatin, mucus, albumen; all the animal acids—spermaceti, hog's lard, train oil, and other fatty substances; ozmazome, urea, sugar of milk; together with many other matters enumerated by chemists, only some of which are peculiar to the animal kingdom;—so that there is no difference between albumen obtained from a vegetable and that which forms, in nearly a pure state, the white of an egg. Albumen in a solid form constitutes the principal part of the almond, and of the kernels of nuts. The juice of a West Indian plant (*Hibiscus esculentis*) contains liquid albumen in such quantities, that it is employed in Dominica as a substitute for the white of eggs in clarifying the juice of the sugar cane. Albumen is common to the vegetable as well as the animal kingdom, and may be easily distinguished from other substances by its property of coagulating or becoming hard and permanently solid by the action of moderate heat, or of acids. It forms a constituent of the serum of blood, of several of the animal secretions, and in a solid form of some of the organized structures of the body. Its composition, from whatever source it may be obtained, is Carbon, 52; Hydrogen, 7; Oxygen, 23; and Nitrogen 15 parts, (rejecting fractions,) in every 100.

Let us trace a few more of these comparisons, bearing in mind that nitrogen, as one of the elements into which both vegetable and animal compounds are ultimately resolvable, exists always in greater proportion in flesh, than in grasses. All animal matters do not contain nitrogen; nor are all vegetable substances devoid of it.

Vegetable *gum* is analogous to animal *mucus*. *Gum* is a substance which exudes from certain trees; it appears in the form of a thick fluid, but soon hardens in the air, and becomes solid, when it appears white, or yellowish white, and somewhat brittle. The characteristic properties of gum are its easy solubility in water, and its insolubility in spirit of wine. All the varieties of gum âre nutricious as food. Gum is composed of 43 carbon, 51 oxygen, and 6 hydrogen, in 100 parts, or nearly. Mucus, a secretion

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found on the surfaces of the lining membrane of the intestines, possesses the same characters; and its composition is nearly the same. It may be obtained by evaporating the saliva to dryness; and is then similar to gum-arabic in its general appearance, but rather more opaque. It may be procured also by evaporating to dryness the fluid found in the shell of the oyster, or water in which that animal has been macerated.

Sugar is essentially the same, whether derived from the maple-tree, the sugar-cane, the milk of animals, or even from the urine in the disease known by the name diabetes. Its composition is 28 carbon, 8 hydrogen, and 64 oxygen, in 100 parts, differing not very widely from gum. Sugar exists, naturally formed, in many plants and fruits, especially the sugar-cane. During the Peninsular war, it was largely manufactured from the juice of the beet-root, both in France and Germany. It has also been obtained from grapes, from manna, from carrots, and from honey.

Let us compare *vegetable* gluten with *animal* gelatin. First, of gluten. It may readily be prepared from wheat, or from flour, by the agency of cold water, and pressing out the starch. It has a grey colour; is elastic, ductile, and tenacious; soon decomposing when kept long in contact with the air, emitting an offensive odour similar to that of putrid animal matter. Gluten, when burnt, affords similar products to albumen, or white of egg, and differs little from it in composition. It is found in a great number of plants: in acorns, chestnuts, apples, rye, barley, wheat, peas, and beans; in the berries of the elder, and in grapes. Gluten appears to be one of the most nutritive of the vegetable substances; and wheat seems to owe its superiority to other grain, from the circumstance of containing it in larger quantities. *Animal gelatin*, its counterpart from the animal kingdom, enters largely into the composition of many of the animal solids; such as horns, hoofs, and skin, the organized structure of bone, cartilage, and tendon. Isinglass and common joiner's-glue are forms of gelatin, it being readily distinguished from all animal principles by its easy solubility in boiling water. Gluten and albumen, derived from vegetables, differ from other vegetable products, principally in containing nitrogen, and thus assimilating very closely to the chemical character of animal matter. Its composition is 47 parts of carbon, 8 of hydrogen, 27 of oxygen, and 18 nitrogen, in 100 parts, or pounds.

Woody fibre is a substance remaining after the plant subjected to analysis has been exhausted of all its soluble materials by repeated boiling in water and spirit of wine. It forms the bulk of vegetables. Its composition is 52 parts of carbon, and 48 of hydrogen and oxygen, in such proportions as form water, in 100 parts. *Animal fibrin* is a principal constituent of the muscular, red or fleshy parts of animals, and of the blood. It may conveniently be procured by stirring blood recently abstracted, during its coagulation; then washing the fibres till they become colourless, or by digesting small pieces of lean meat in repeated portions of water. As vegetable charcoal is made largely from woody fibre subjected to the action of a close fire, so animal charcoal may be similarly prepared from the muscular parts of animals by the same agency; or, indeed, from any organized structure containing carbon. In animal fibrin, as it exists in muscle or in blood, one-half the weight is carbon. Fibrin is white, inodorous, and insipid; when dry, it is hard, brittle, and slightly transparent. Strong sulphuric acid blackens it, converting it into charcoal precisely as it does wood. In the roots of plants, in the trunk and branches of trees, the bark and heart-wood, the leaves and flowers, the great basis of the solid parts is woody fibre. It forms by far the greatest part of the heart-wood and bark; there is less in the alburnum, still less in the leaves and flowers. Fibrin holds a similar relation to animal bodies. In 100 parts of fibrin there are 53½ of carbon, hydrogen 7, oxygen 19, and 19 of nitrogen; the presence of nitrogen, or its addition, constituting the peculiarity which distinguishes fibrin from woody fibre.

We have run the parallel far enough for ordinary purposes. Of course, there are some proximate compounds in animals and vegetables which are not common to both, though, with the usual addition of another element, nitrogen, the most varying and unlike substances derivable from the animal and vegetable world are compounded from the same ultimate elements. Let us next briefly glance at a few of these.

Starch.—Starch is procured from different vegetables, but particularly from wheat, or from potatoes. To make starch from wheat, the grain is steeped in cold water till it becomes soft, and yields a milky juice by pressure; it is then put into sacks of linen, and pressed in a vat filled with water: as long as any milky juice exudes, the presure is continued, the fluid becomes gradually clear, and a white powder subsides, which is starch. *Arrow-root*, *tapioca*, and *sago*, are nearly pure starch. Starch, or, in its absence, coagulated mucilage, forms the greatest part of the seeds and grains used for food; and they are generally combined with gluten, oil, or albumen: in corn with gluten, in peas and beans with albumen, and in rape-seed, hemp-seed, linseed, and the kernels of most nuts, with oils. Its characteristic property is its easy solubility in boiling-water, and its insolubility in that fluid when cold. The ultimate composition of starch is, carbon 43½, oxygen 50, hydrogen 6½; or, in other words, carbon 43½, and oxygen and hydrogen in such proportions as form water; differing, chemically, from gum, only in a very slight variation in these quantities.

Extract, or the *extractive principle*, exists in almost all plants. It may be procured in a state of tolerable purity from saffron, by merely infusing it in water, and evaporating the solution. It may likewise be obtained from catechu, or *terra Japonica*, a substance now imported in immense quantities from India, and used in calico-printing. This substance consists principally of astringent matter and extract. By the action of water upon it, the astringent matter is first dissolved, and may be separated from the extract. There are almost as many varieties of extract as there are species of plants. It is not, nor can it be used singly as an article of food; but is probably nutritive when united to starch, mucilage, or sugar. Its composition is carbon, hydrogen, oxygen, and a little nitrogen.

Tannin, or the *tanning principle*, may be procured by the action of cold water on bruised grape-seeds, or pounded gall-nuts, and by the evaporation of the solution to dryness. It is a yellow, highly-astringent substance. If tannin be distilled in close vessels, the principal products are charcoal, carbonic acid, and inflammable gases, with a minute quantity of volatile alkali. Hence its ultimate elements seem the same as those of extract, but probably in different proportions. Tannin is not a nutritive substance, but is of great importance in its application to the art of tanning. When skins (which are composed almost entirely of gelatin or jelly) are exposed to solutions containing tannin, they slowly combine with that principle; their fibrous texture and coherence are preserved; they are insoluble in water, and no longer liable to putrefaction; and, by subsequent processes of rolling and drying, form leather. In general, in this country, the requisite tannin is made from the bark of the oak; but the barks of other trees, and the wood and leaves of many shrubs, yield it abundantly.

Resin is very common in the vegetable kingdom. One of the most usual species is that afforded by the different kinds of fir. When a portion of the bark is removed from a fir-tree in spring, a matter exudes, which is called turpentine. By heating this turpentine gently, a volatile oil rises from it, known familiarly as "spirit of turpentine." A more fixed substance remains, which is common yellow rosin. Resins are insoluble in water, but very soluble in spirit of wine; in this respect reversing the character of gum. Sandarac, copal, mastic, elemi, are resins obtained from various trees; and the list is very numerous. Tar and pitch principally consist of resin in a partially decomposed state. Tar is made by slowly burning the fir; and pitch, by the evaporation of the more volatile parts of tar. One hundred parts of common resin contain 76 of carbon, 13.3-10ths of oxygen, and 10.7-10ths of hydrogen.

Wax is found in a number of vegetables, from their berries and the surfaces of their leaves. Its combustible property, like that of resins, is well known. The wax of the vegetable kingdom seems to be precisely of the same nature as that afforded by the bee. Its constituents are, carbon 81.7-10ths, oxygen 5½, hydrogen 12.6-10ths, in 100 parts.

Fixed oil is obtained by expression from seeds and fruits. The olive, the almond, linseed, and rape-seed, afford the most common vegetable fixed oils. Their common properties are well known. They are lighter than water; and many of them congeal at a lower temperature than that at which water freezes. They all require, for their evaporation, a higher temperature than that at which water boils. The products of the combustion of oil are, water and carbonic acid gas. The fixed oils are very nutritive substances: they are of great importance in their applications to the purposes of life. Fixed oil, in combination with soda, forms the finest kind of hard soap. Let us compare the ultimate analysis of olive or *vegetable* oil with that of spermaceti oil, which is of *animal* origin :—

OLIVE OIL.		SPERMACETI OIL.	
Carbon, . . .	77.2-10ths	Carbon, ...	50.
Oxygen, . . .	9.4-10ths	Oxygen, ...	5.
Hydrogen, . .	13.4-10ths	Hydrogen, ...	45.
	100.		100.

The greater proportion of hydrogen in spermaceti oil renders it a fitter fluid for combustion in lamps than *vegetable* fixed oils; but the ultimate composition of the two, as far as the *list of ingredients* is concerned, is evidently the same.

Hog's lard, butter, spermaceti, may be regarded as animal fixed oils.

Volatile, or *essential oils,* differ from fixed oils, in being capable of evaporation by a much lower degree of heat Volatile oils give the peculiarity of odour to the peppermint plant, to camomile, and numberless other shrubs and trees; existing in the flowers of some of them, and in the leaves and inner bark of others. Thousands of minute insects may usually be seen in the stalk and leaves of the rose; but none of them are ever observed on the flower. One reason for the existence of fragrant volatile oil in plants may be, the preservation of the parts destined to the propagation of the species from the destructive ravages of insects and animalculæ which feed on the bodies of plants. So, those woods that contain aromatic oils are remarkable for their indestructibility, as cedar, rose-wood, and cypress. The volatile oils inflame with more facility than fixed oils; and afford, by their combustion, different proportions of the same substances—namely, water, carbonic acid, and charcoal or carbon. Volatile oils consist of carbon, hydrogen, and oxygen; but, as yet, no accurate experiments have decided their relative proportions.

The *bitter principle* is very extensively diffused in the vegetable kingdom. It is found abundantly in the *hop*, in the common broom, in camomile, and in quassia. The natural bitter principle is of great importance in the art of brewing. It checks fermentation, and preserves fermented liquors, and doubtlessly plays an important part in the healthy nutrition of the living vegetable. An intensively bitter substance is found in bile, or the fluid secreted by the liver of animals. The gastric juice, or fluid secreted by the stomach, is not only the principal solvent in digestion, but has the same antiseptic property, or resists putrefaction as strongly as the vegetable bitter principle.

Systematic writers on chemistry have enumerated a long list of proximate constituents, both of animal and vegetable structure. Many of them, as we have seen, are but the counterparts of each other. It is needless to specify them all.

The earths found in plants are four, all of them, as previously related, of metallic origin. These are, 1*st*, Silica, or the earth of flints, the base of which is the metal silicon; 2*d*, Alumina, or pure clay, the base of which is the metal aluminium; 3*d*, Lime, the metallic base of which is calcium; and, *4thly*, Magnesia, the metallic base of which is magnesium. All of these are similarly found in animals; among them, lime, most largely in their bones and shells. Some insects are almost entirely composed of silica: iron, existing in peat-mosses and in many vegetables, gives the red colour to the blood. None of these exist in a free or uncombined state, in either the vegetable or animal world; most commonly in combination with acids, of which we may observe, that some plants contain free vegetable acids in large proportion, as the common sorrel or sour-leaf. The applications of the vegetable acids are well known. The agreeable taste and wholesomeness of various vegetable substances used as food, materially depend upon the vegetable acid they contain. Phosphoric acid (united to lime in bones) is found free in the onion; and the sulphuric, muriatic, and nitric acids, though they cannot with propriety be considered as vegetable products, exist in many saline compounds, as part of the inorganic constituents of plants as well as animals. They are all variously compounded of carbon, hydrogen, and oxygen. Then, too, the saline compounds found in plants correspond with many similar compounds found in animals. Potash and soda, blended with acids, are found in blood, in the various animal secretions, in the leaves and stalks of vegetables; sparingly in animal matter, very largely in sea-weed yielding soda, and in the ashes of burnt wood yielding potash.

Plants, like animals, are produced by ordinary generation; and though we meet with various instances of production by the generation of buds and bulbs, or of slips and offsets, the similarity, instead of being hereby diminished, is only drawn the closer; for we meet with just as many instances of the same variety of propagation among animals. Many species of worms are capable of increase by buds, bulbs, or offsets; and some of these animals, like the house-leek and various grasses, by spontaneous separation. A twig of myrtle will live and grow, if placed in the ground, because it contains in itself all the parts of a perfect plant; but that is independent of the provision nature has made for the propagation of the plant naturally, from the seed buried in the earth. Something approaching very closely to the character of a sexual, or reproductive system of organs, is visible in the flowers of plants. The pistil is the organ which contains the rudiments of the seed; but the seed is never formed, as a reproductive germ, without the influence of the pollen, or dust on the anthers. This mysterious impression is necessary to the continued succession of the different vegetable tribes. It is a feature which extends the resemblances of animal and vegetable existence, and establishes, on a great scale, the beautiful analogy of nature. Seeds which are shed devoid of this fructifying dust, are precisely analogous to eggs over which the influence of the male bird has never been exerted. Vitality is therefore essential to the germination of seeds: life will remain dormant, inert for an indefinite period,—and then change its form into that of active vitality, if that seed be placed under the action of moisture, heat, and air. So that the scriptural inquiry, "How can a seed quicken, unless it die?" is not to be taken as the enunciation of a scientific truth, but as an illustration drawn from the ordinary apprehensions of mankind.

The utmost period of time to which seeds may be kept, and be enabled to retain their life, and, consequently, their power of growth, has not been accurately determined; but we have proofs enough to show that the duration may be very long. A paper of melon seeds, found in the year 1762 in a cabinet of Lord Mortimer, and apparently collected in 1660, were then sown, and produced excellent fruit; and, more latterly, seeds buried in the ruins of Herculaneum, and others brought from Egypt,—found in the tombs that are more ancient than the time of Moses,—have been proved to retain their vitality. *Animal seeds*, or, more properly, EGGS, when perfectly impregnated, appear capable of preservation quite as long. This inert condition of seeds is not unlike what occurs in the hollows of our waste lands, in reference to animal matter. When these have been for some time filled with stagnant water, we not unfrequently find minute eels, minnows, and water insects there, and wonder how they could get into such a situation. But the mud which has been emptied out of a fish-pond has been, perhaps, thrown into these very hollows; or the eggs of the animals or insects have been carried, mixed with other materials, into the same place, and then waiting, it may be, year after year, the accidental, yet necessary, circumstances of warmth, water, light, and air, they have been stimulated to active life. One species of locust appears, *in numbers*, only once in seventeen years; and the palmer-worm once only, in similar numbers, in thirty years. Something analogous to this occurs in reference to various species of grub and fly, as observed by practical farmers; and the reason of it is, that the integument, or outer covering, of many minute ova, ensures their protection and their vitality during long periods. The eggs of the gad-fly could never be hatched on the horse's back: their covering preserves them entire and vital, till, by the itching sensation their presence excites, the animal is tempted to lick the spot, and so convey them to his stomach, the only place where it is destined they should come to maturity. Numberless small fish are seen in the salt pans at a village in Hesse Darmstadt: the ova of these fish have been conveyed there by birds, and, it so happens, are deposited in a place where the necessary conditions exist for their development.

The essential difference between the egg of a barn-door fowl, and the ovum or egg, which ultimately becomes a calf, a foal, or a human being, is, that the one, after the stimulus of impregnation has been applied to it by the male, comes to maturity *within* the body of its parent; in the other instance, it is *hatched* after its expulsion. In fish and in frogs, the spawn, or ova, is first expelled, then the male passes over it. The seeds of plants are exactly analogous to eggs; in ordinary instances the germs and the fecundating material which ensures reproduction, being both found in the same flower, and, of course, attached to the same stalk. The various species of *fruit* are but contrivances for the shelter and preservation of seeds, as the pippins of the apple, or of the orange and lemon: these, when fully ripe, left to themselves, would fall, become rotten, or, in other words, subjected to common chemical agencies and exposing the seed within, form, in the first instance, a manuring material for the perpetuation of the plant or tree which had yielded it.

Plants derive all their sustenance from the spot on which they are placed; and, solely for this reason, are not provided with a peculiarity which distinguishes animals, namely, a set of movable levers or bones, destined to carry them about from place to place in quest of food, and of muscles, or red, fleshy, contractile organs, intended to act upon those passive levers: and yet there are some plants that seem fairly entitled to the character of locomotive or migratory. A familiar instance of this occurs in the *strawberry* genus: such plants grow from a new bulb, or knob, or radicle, while the old root dies away; in consequence of which, we can only conclude that the living principle of the plant has quitted an old, decayed, and ruinous mansion, to take possession of a new one; so much so, that were a person to plant the orchis, or the devil's-bit, in his garden, and to search for it in the same spot, after an interval of seven years, he would find it several hundred yards from the spot where he had planted it.

There are some creatures that throw off their outer covreing annually: so the shrubby cinquefoil, indigenous to Yorkshire; and other plants and trees, which, sending forth, every spring, new colonies, by means of runners, (as we call them,) shortly obtain a settlement for themselves, and break off all connexion with the parent stock.

The blood of plants, like that of animals, is of an extremely compound character. If blood be allowed to stand n a vessel, it soon separates into a clot, and a fluid in which that clot floats. Each of these is again divisible into several other matters. So with the fluid that circulatesin the vessels of a tree. And, as from blood the various dissimilar solid and fluid secretions and excretions are formed, building up the animal fabric,—as bone, muscle, bile, urine, jelly,—so, from this common current of vitality, the *sap*, plants, like animals, secrete a variety of substances of different, and frequently of opposite powers and qualities—substances nutritive, medicinal, or destructive. The flesh of the viper is healthful, his poison is deadly; the root of the Indian cassava is poisonous, its leaves are eaten as ordinary food. Every one is familiar with the fact, that some of our domesticated animals will eat with impunity vegetables that would be poisonous to others. Then, too, how close is the analogy between the torpidity of the squirrel, or the dormouse, or the swallow, during the winter, and that of deciduous plants during the same season: we know, that if proper care be exercised, they may be removed in that state without endangering their vitality. Many animals are amphibious—they can live equally well on land or in the water; and the vegetable world is not without illustrations of a similar power. Indeed, the instances of resemblance between animal and vegetable life are innumerable. Some vegetables, like a few birds, more insects, and most of our forest beasts, appear to sleep through the day, and become active at night; while the greater number of them, like the great majority of animals, fold or hang their leaves at sunset, and appear invigorated with the return of morning. Like animals, the duration of their existence is equally various.

We have already observed, that plants and animals convert the materials of nutriment they receive into their own substance precisely by the same agency, and that there is no essential difference between the *ultimate* composition of the requisite materials in either instance. If this be so, as in the further progress of this inquiry we shall unquestionably prove, it would be fair to expect that the digestive organs of animals,—in fact, all that is connected with reproduction and growth,—have their counterpart in plants; and such is actually the case. Let us briefly review the *anatomy*, or organized structure, of a plant, and compare that structure with the anatomy of a horse.

Every plant, examined as to external structure, displays, at least, four systems of organs, or some analogous part. First, the *Root;* Secondly, the *Trunk* and *Branches*, or *Stem;* Thirdly, the *Leaves;* and, Fourthly, the *Flowers* or *Seeds*.

The stem of any tree consists of the pith in the centre, the wood surrounding the pith, and the bark which covers the whole. A tree completely divested of bark, is precisely in the predicament of an animal deprived of its hide. The pith consists of bundles of minute hollow tubes, or vessels arranged horizontally; the wood and inner bark, of long tubes or vessels bound together in a vertical position, so as to be capable of carrying vegetable blood up and down between the roots and leaves. When a piece of wood is sawn across, the cut ends of these tubes are as distinctly perceptible as the divided arteries and veins in the stump of an amputated limb. Branches are only prolongations of the stem, and have the same character.

The bark of the stem and root is divisible, like the covering of animals, into *epidermis*, (analogous to the scarf skin which rises over a blister,) and *true skin*, or *inner bark*, which alone is vascular and vital. In forest trees, and in the larger shrubs, the bodies of which are firm, the outer bark, epidermis, or scarf skin, is a part of little importance; but in reeds, grasses, and plants having hollow stalks, as wheat and oats, it is of great use, and is exceedingly strong, from the provision of its containing siliceous earth, or the oxide of a metal, as already stated. The analogy between this contrivance and the shell of the lobster, or the covering of insects, is very obvious.

As the *root* tapers away, the pith gradually disappears, the bark thins out, the wood softens, till the white tendrils, of which its extremities are composed, consist only of a colourless, spongy mass, in which the vessels or tubes that carry on the circulation lose themselves.

The leaf is an expansion of the twig. Each separate leaf is precisely analogous in its action to the gills of a fish, or the lungs of an ox, or of a human being. The fibres which are seen to branch out from the base over the inner surface of the leaf, are prolongations of the vessels of the wood, precisely as the lung of an animal is but an outspread division of blood vessels. A powerful sucking and forcing pump called the *heart*, is essential to drive human blood along large vessels to its ultimate division; but the vessels of plants are *capillary*, that is hair-like, exceedingly minute, and therefore a central power or heart is not necessary. So there are capillary vessels in animals, and there the action of the heart is not so sensibly felt. Their minuter blood vessels are believed by some to be contractile. The green exterior portion of the leaf is a continuation of the inner bark, and communicates directly with its vessels. Most of the vessels of the living plant are full of sap or vegetable blood in almost continual motion. In spring and autumn the motion is more rapid; in winter it is sometimes scarcely perceptible. From the spongy part of the root the sap ascends through the vessels of the wood in virtue of that capillary attraction already adverted to, until it is diffused over the inner surface of the leaf. By the vessels in the *green* of the leaf it is returned to the bark, and through the vessels of the inner bark it is returned to the root. In man and four-footed animals the blood is driven from the heart along the arteries, and returns back by the veins; but previously to being sent along the circulation a second time, it is driven into the lungs, is there subjected to the action of the air, (whence the necessity for breathing,) and then, returned to the other side of the heart, is again fitted to recommence its journey. Animals derive a considerable portion of their nutriment from the change effected on the air by the action of the lungs: something is absorbed as well as given out. The leaves of plants perform the same office. In the sunshine, the leaves are continually absorbing carbonic acid as well as other matters from the air, and giving out oxygen gas. In breathing, carbonic acid is given off, and not triflingly. The air becomes instantly poisonous, if that gas accumulate as rapidly as it did when some hundreds of our brave countrymen were pent up in the confined space of the "black-hole" at Calcutta. The leaves, then, are continually appropriating carbon, the basis of charcoal, from the atmosphere. When night comes, this process ceases, and they begin to absorb oxygen and give off carbonic acid. Hence the mischief of placing large plants, in great numbers, in bedrooms. It would result from the above arrangement, that plants grow very little, perhaps not at all, during the night. Now, during the summer months, when they are provided with leaves, the days are long, the nights short; in winter, when plants are torpid or stationary, the nights are long, and the day comparatively brief. Sunshine is necessary, in order to enable plants to decompose carbonic acid and appropriate the carbon. It is owing to this law, that in the cold northern regions where, in their highest latitudes, the sun once risen never sets again during the whole of their short summer, vegetation almost rushes up from the soil; almost literally, plants may be *seen* to grow. The green leaves are continually gaining from the air and never losing; ever taking in and never giving off carbon, since no darkness interrupts or suspends their labors.

Every child is led to regard the *root* of a plant as the organ from which the vegetable *grows;* not merely as attaching it in the erect position to the spot, but as forming the medium of communication between all that is above ground, and the food the soil is supposed to yield. But it is not so obvious to us, who, in many senses, are but children of a larger growth, that the leaves of an oak or an ash spread their broad leaves into the air for the very same purpose as the roots diffuse their fibres through the soil. The only difference is, that while the roots absorb chiefly liquid, the leaves inhale almost solely gaseous food. The human lungs expose the blood to air just as, in the leaf, the sap is submitted to the same agency; and in each instance there is a double use to which these organs are destined: they not only change the character of the circulating fluid, but permit, by the decomposition of air, the absorption of some of its elements as food for the animal or plant. So that, in truth, *we live and are nourished partly upon the air we breathe*, and *so is a cabbage* upon the atmosphere it decomposes. If the experiment be repeated—it has often succeed—that of burying the branches of certain trees in the soil and elevating the roots in the atmosphere, turning the vegetable upside down—there is as it were an inversion of its functions—the roots will produce buds and leaves, and the branches shoot out into root-like fibres and tubes. The experiment succeeds well with the willow.

Though plants give out in the nlght carbonic acid, this process does not go on so rapidly, or to such an extent, as to destroy the balance in their favour of what has been absorbed during the day. The quantity absorbed through the leaves varies with the season, the climate, and the kind of tree; it is also modified by the nature of the soil. It has been ascertained, however, that in our climate, on an average not less than from one-third to three-fourths of the entire quantity of carbon contained in the crops we reap from land of average fertility, or (pretty nearly) the amount of charcoal a burnt hay-stack would yield, is really obtained from the air.

The varied and equally important uses of a leaf appear, to the contemplative mind, singularly beautiful.

> "In human works, though laboured on with pain,
> A thousand movements scarce one purpose gain;
> In God's, one, single, can its ends produce,
> Yet serves to second, too, some other use."

Then, too, the contrivance of so *many* expanded leaves! The air contains only one gallon of carbonic acid in every 2500; and this fortunately, rather we ought to say *designedly*, only in a state of *mixture*, not of combination, with the elements of the atmosphere, and therefore more easily separable; were the proportion larger, it would prove poisonous to the animals that live in it, deriving also a portion of their nourishment from *another* element of the atmosphere equally essential to plants. Now, in order to catch this minute quantity of carbonic acid, the tree hangs out thousands of square feet of leaf, in perpetual motion through the ever-moving air; and thus, by the conjoined labours of millions of pores, the substance of whole forests of solid wood is slowly extracted from the fleeting winds. Is not this wonderful! Green stems, and stalks of grasses, absorb carbonic acid as the leaf does; and thus a larger supply is afforded when the growth is most rapid, or when the short life of the annual plant demands much nourishment in a limited time. The slender and comparatively dry leaves of the pine and the cedar perform the same functions as the large and juicy leaves of the fig-tree, the cabbage, the walnut, or the rhubarb plant. That plants derive so large a proportion of their nutriment, not from the soil, but from the air, is evident from observing the habitudes of many found in hot climates, which refuse to vegetate except in a soil so dusty that no moisture can be extracted from it, and perish if water be ignorantly supplied to them. A well-known Jamaica shrub was long propagated in our own stoves by cuttings, which, though freely watered, could never be made to produce any signs of flowers or fruit, notwithstanding that the cuttings were several feet in length every season. By accident, a pot with young cuttings was mislaid and forgotten in the royal garden, and having no water given it, it was thereby reduced to its healthy dryness, and then every extremity was seen to produce a flower. It is an opinion common to many able men of the present day, that *many* plants derive the *whole* of their support from the surrounding atmosphere; if this be true of some, it is partially true of all, and must very materially modify all our plans intended to increase the product of the soil. There are, we say, some plants which have *no root* whatever, as in the prickly-pear or Indian fig; many are attached only to the hard surface of a stone, and propagate their kinds by offsets, without any other vegetable organs. Now there are some quadrupeds that appear to derive nourishment in the same way. The *sloth* never drinks: it imbibes moisture by its skin, it trembles at the feeling of rain; so the olive cavy, and the ostrich, are noted by the Arabs as avoiding water, and yet these creatures are as juicy and well supplied with fluids as any with which we are acquainted.

If leaves are necessary for the existence of the individual tree, the FLOWERS are necessary as generative organs for the continuance of the species. Even in that class of plants where no flowers are distinct, still there is every reason to believe that the production of the seed is effected in the same way as in other plants. Mosses and lichens, which belong to this family, have no distinct roots, but they are furnished with filaments which perform the same functions; and even in mushrooms there is a system for the absorption and exposure of the sap to the air. Of all parts of plants the flowers are most refined, the most beautiful in their structure, and appear as the master-work of nature in the vegetable kingdom. The elegance of their tints, the variety of their forms, the delicacy of their organization, and the adaptation of their parts, are all calculated to awaken our curiosity and excite our admiration. The ancients had observed, that different date-trees bore different flowers; and that those trees producing flowers, containing in their centre organs termed by botanists "*pistils*," bore no fruit unless in the immediate neighbourhood of such trees as produced flowers differently arranged in their central structure, and containing "*stamens*." The great naturalist, Linnæus, has arranged the whole Vegetable Kingdom into twenty-four classes, as deducible from the *numbers* of these sexual organs in each flower. The numbers of the *stamens* and *pistils* in each, their arrangements or their division, are the circumstances which guided him, and enabled him to form a system of botany admirably adapted to assist the memory, and denoting well the analogies of all the essential parts of plants.

The SEED, the last production of vigorous vegetation, is wonderfully diversified in form. Being that part which is of the highest importance, it is found defended above all other parts of the plant; sometimes by soft pulpy substances, in addition to a hard shell, as in apricots and plums; by thick membranes, as in common garden peas and beans; by hard shells, or a thick coating, as in corn and grasses. So, similarly, the eggs of the ostrich, which are destined to be hatched by the sun in the sand where they are deposited, are invested with a strong shell, not firmer, comparatively, than the encasement surrounding every one of the myriads of ova or eggs in the roe of a cod-fish or herring. If we were to pursue the analogy more closely still, between the structure of a grain of wheat and that of the egg of a bird or the ovum of a quadruped, we should find the parallelism singularly minute and exact; but this is the province of the physiologist: it is enough for our purpose to cite a familiar illustration. When potatoes are cut in pieces for seed, every gardener knows that, if each separate piece have not an "eye" upon it, the fragment will not grow. If it vegetate, it will be from that living spot or "eye:" the remainder will serve to minister nutriment to the infant plant before it can pierce the soil; it will strike upwards and downwards; the original bit of potato will be absorbed, or perish. So, a common garden bean is divisible into two equal halves or lobes, which form the organ of nourishment; but the young plant springs not from these, but from the plume or small white point between their upper part, and the young root is found like a small curved cone at the other end of the seed. In wheat, and many grasses, the organ of nourishment is not divisible as in a bean; but the same principle holds true not only of all *seeds*, but of bird eggs, and the rudimentary ova of all animals.

CHAPTER IV.

Of the Elementary Composition of *Water;* of the Composition of the *Atmosphere;* and of the artificial Application of Water to Grass Lands.

We have already traced some of the more prominent analogies obviously existing between vegetables regarded as *alive*, and animals. We have shown that the ultimate, and many of the proximate, elements of both are the same —that they are nourished or destroyed by the same agencies. Before we describe minutely the nature of the process of *nutrition* and growth, it is necessary to understand the chemical composition of the ATMOSPHERE, which is related similarly to lungs as to leaves; and of WATER, necessary alike to plants as to animals.

If one measure of hydrogen gas, and half as much oxygen gas, or, by weight, eight grains of oxygen gas, and one grain of hydrogen, be mixed in a dry glass over mercury, and the mixture set on fire, the result will be the formation of *pure water*. So water is formed, and is sometimes seen collected, from the burning of the common carburetted hydrogen, in the street or shop gas-lamps; the effect being nothing more nor less than the combination of the oxygen of the air with the burning hydrogen. Water is the result of their union, and combustion, or burning, EFFECTS that union. The gas in the pipes would not, could not, burn, if a free supply of air, or rather of oxygen, contained in that air, were cut off; and *water* is the PRODUCT of their union. So that perfectly pure water is, chemically speaking, not a simple undecompounded element, but a compound of two elements—*oxygen* and *hydrogen;* both of which, as elements, enter largely into the composition of both animal and vegetable matter. Oil and fat owe their utility in yielding light in lamps to the presence of hydrogen. Its presence causes turpentine and rosin to blaze and burn readily; while oxygen is equally an ultimate ingredient in all vegetable and animal substances. These details may appear scientific; but the action of manure is not to be understood without them, or rather the nature of vegetable and animal growth, and all that favours or retards it.

The purest NATURAL water we can obtain is procured by melting snow, or collecting rain-water, in stations distant from the smoke of a town. If *pure* water be requisite for the experiments of a chemist, it is generally obtained by distilling rain-water in glass vessels,—that is, raising it into steam by heat, then allowing that steam to condense, by passing it through cold pipes. The characters of *absolutely pure* water are—that it is perfectly transparent and colourless, limpid, not sparkling, insipid, unpleasant, and sickly to the taste, and is lighter than common river or spring water. One hundred cubic inches of water weigh 252½ grains; it is 828 times heavier than air; and when expanded into steam, occupies 1700 times its previous space. Steam is not nearly so heavy as the air. Water readily absorbs many gases: what is called soda-water, is water impregnated with fixed air, or carbonic acid gas. It absorbs ammoniacal gas readily in large quantities, forming what is sold in the shops as spirit of hartshorn.

Of the constitution of SEA WATER, the proportions and nature of its saline ingredients, one of their final uses in vegetation, and especially the relatively large proportion of carbonic acid it contains, we will speak, when adverting to the necessity and wisdom of such arrangement.

Neither is the ATMOSPHERE animals breathe and decompose, and in which living plants carry on analogous operations, a simple element. *Air* is a compound of two gases, *oxygen* and *nitrogen*, in the proportion of two parts of *nitrogen* to one of *oxygen.* 100 cubic inches of air weigh 30 grains. The atmospheric pressure of the air upon the earth's surface, at the level of the sea, is equal to a weight of 15 pounds upon every square inch, and is capable of supporting a column of water 34 feet high, or of mercury, 30 inches. For this reason, a pump will not work, if the depth of the shaft be greater than 34 feet; and the height to which the quicksilver will rise in the weather-glass always corresponds to the pressure of the atmosphere; that is to say, the weight of the mercury in the tube is exactly equal to the weight of a column of air the same thickness, only the height of the atmosphere. The air receives its heat entirely from the earth: hence the phenomena of cold which we perceive the higher we ascend from the earth's surface.

If water be passed through a red-hot gun-barrel, it will be decomposed; its oxygen will unite with the metal, its hydrogen will escape, and may be collected in the form of a gas, and preserved in a bladder. Many similar experiments demonstrate the composition of water. It may be *made*, in fact *is* made, in almost every instance where a combustible body unites with the oxygen of the air: it may be separated into its elements, *unmade*, so to speak, by a variety of processes. *Synthesis* is the term chemists apply to the former; *analysis* to the latter mode of demonstrating its composition.

Now, it is most materially important, in connexion with our future inquiries, to observe, that there are other matters, not essential to the composition *either of* AIR *or* WATER, *that* IN NATURE *are always found mechanically mixed up or associated with each, and this as an express provision for the sustenance of animals and plants.*

The atmosphere is not compounded purely of oxygen and nitrogen: it contains *carbonic acid* and *watery vapour.* The proportion of carbonic acid in the atmosphere may be regarded as equal nearly to one part in a thousand, estimated by weight. The quantity varies according to the seasons, but the yearly average remains continually the same.

And the rain that descends from the clouds contains *ammonia,* one of the elements of which, as previously stated, is nitrogen. Experiments confirm the theory upon which the presence of ammonia in rain-water might reasonably be expected. If a few hundred pounds of rain-water be carefully subjected to distillation, and the first two or three pounds evaporated, with the addition of a little muriatic acid, a very distinct crystallization of muriate of ammonia, or *sal ammoniac,* may be obtained, which crystals have a brownish-yellow colour. If a little sulphuric or muriatic acid be added to a quantity of rain-water, and the mixture boiled to dryness, the ammonia remains as the residue, in combination with the acid employed; and it may be detected by the addition of a little powdered lime, which, combining with the acid, sets the ammonia free, and is recognised by its pungent smell. The sensation which is perceived upon moistening the hand with *rain*-water, so different from that produced by washing it in *pure* distilled water, and to which the term *softness* is applied, is owing to the presence of carbonate of ammonia in rain-water.

How this ammonia is generated in rain-water, the importance and utility of the fact, and the uses of carbonic acid in the atmosphere, are matters so closely identified with living processes in animals and plants, that we must here simply confine ourselves to the statement. We have now the *preliminary materials* for the examination of nutritive actions. When these, as they exist naturally, are understood, we shall be able to say what are those substances called FERTILIZING, which may be useful in given instances as manure, whether their application may be suitable or injurious; just as a knowledge of anatomy and physiology is necessary to the physician who would amend the diseased conditions of the body. He must know what is the nature of *healthy* and *ordinary* action in the living frame, before he can understand and alter diseased action.

The artificial application of *water* in large quantity to the land, is a subject well understood, and its effects accurately marked and recognised in many parts of the world that have been regarded as strictly agricultural localities during a long succession of ages. Irrigation is, in truth, a mode of applying the weakest of liquid manures, on a very bold scale, to grass-lands. Almost every farmer has a mode of accounting for the highly-fertilizing effects of rigation. Davy added another to the list of explanations. He thought that a winter-flooding protected the grass from the injurious effects of the frost. He examined, with a thermometer, and with his usual address, the water-meadows near Hungerford, in Berkshire, and ascertained that the temperature of the soil was ten degrees higher than the surface of the water, and that, too, on a frosty March morning. He remarked, also, a fact that most farmers will confirm, that those waters which breed the best fish are ever the best fitted for watering meadows.

He appears, however, never to have steadily investigated the chemical composition of river-water with regard to its uses in irrigation; and in consequence, he knew little of the value of some of its impurities to vegetation. Thus, if the river-water contains gypsum, (sulphate of lime,) which it certainly does if the water is hard, it must, under ordinary circumstances, on this account alone, be highly fertilizing to meadows, since the grasses contain this salt in very sensible proportions. Calculating that one part of sulphate of lime is contained in every two thousand parts of the river-water, and that every square yard of dry meadow-soil absorbs only eight gallons of water, then it will be found, that by every flooding, more than *one hundred weight* and *a half of gypsum per acre* is diffused through the soil in the water: a quantity equal to that generally adopted by those who spread gypsum on their clover, lucern, and sainfoin crops as a manure, either in a state of powder, or as it exists in peat-ashes.

And, if we apply the same calculation to the organic substances ever more or less contained in flood-waters, and if we allow only 25 parts of animal and vegetable remains to be present in a thousand parts of river-water, then we shall find, taking the same data, that every soaking with such water will add to the meadow nearly two tons per acre of animal and vegetable matters; which, allowing in the case of water-meadows five floodings per annum, is equal to a yearly application of ten tons of organic matter. The quantity of foreign substances present in river-water, although commonly less, yet very often exceeds the proportion we have calculated to exist.

There is no stream more celebrated for its prolific water-meadows than the Itchen in Hampshire; and in no part of England is the system of irrigation better understood and more zealously followed. The water of this river, taken from above the city of Winchester, contains in 10,000 parts, after all its mechanically suspended matters have subsided, about 2.2-3d parts, namely—

Organic matter	0.02 parts.
Carbonate of lime (chalk)	1.89
Sulphate of lime (gypsum)	0.72
Muriate of Soda (common salt)	0.01

The water of lakes is usually still more surcharged with foreign substances than those of rivers; and, from the use of such waters, especially if an occasional or winter stream of water passes through them, we have witnessed great fertilizing effects produced on meadow land.

CHAPTER V.

Of the Nature of Vegetable Growth; the true use of Vegetable Mould or Humus; and of the Sources of the Elementary Constituents of Plants.

From the facts detailed in the foregoing sections, the development or nutrition and growth of a plant requires the presence, first, of substances yielding *carbon* and *nitrogen*, as elements to the growing structure; secondly, of water, furnishing in itself two very important elements, namely *oxyen* and *hydrogen*, besides adventitious matters; and lastly, a soil, to yield the saline, earthy, metallic, or other organic materials essential to vegetable life.

The fertility of every soil is generally supposed to depend on the presence in it of a peculiar substance, named "*humus*." This substance, *incorrectly* supposed to form the principal nutriment of plants, and to be extracted from them by the soil in which they grow, is nothing more than *vegetable mould*, the product of the decay of other plants.

Adherence to the above incorrect opinion, has hitherto rendered it impossible for the true theory of the nutritive process in vegetables to become known, and has thus deprived us of our best guide to a rational practice in agriculture. Any great improvement in that most important of all arts, is inconceivable without a deeper and more perfect acquaintance with the *substances* which really nourish plants, and with the *sources* whence they are derived. It was supposed that by the aid of water " humus" is rendered capable of being absorbed by the roots of plants. If it be, it must be in some altered form; for if a portion of good mould be long subjected to the action of water, that fluid will not dissolve more than a hundred-thousandth part of its weight, and contain only soluble organic matters, and the salts which are contained in the rain-water which has fallen upon it. Decayed oak wood, beech, and fir, yield the same results.

Let us inquire whence the grass in a meadow, or the wood in a forest, receives the carbon essential to the formation of that WOODY FIBRE constituting the principal weight and solid bulk of the tree or plant. Whole tracts of open country in the green wilds of America, immense woods and forests in all parts of the world, receive no carbon in the form of manure; how does it happen that the soil, instead of being exhausted through the annual production of vegetation for ages, becomes every year richer in carbon? In other words, a certain quantity of carbon is taken every year from an unmanured forest or meadow, in the form of growing wood or grasses; and in spite of this, the quantity of carbon in the soil augments; it becomes richer in vegetable mould, in humus—so much so, that in process of time it will not support the trees which stood upon it: they fall, and the surface becomes a peat-moss, burying huge trunks in its bosom. Plants give back more carbon to the soil than they take from it; it is evident, then, that their growth must depend on the reception of carbon as food from another quarter. It is not denied that manure, rightly chosen and applied, exerts an influence upon the growth of plants; but it neither serves for the production of the carbonaceous woody fibre, nor has any influence upon it, because we find that the quantity of carbon produced by manured land is not greater than that yielded by lands which are not manured. The discussion as to what manure really produces, has nothing to do with the present question, which is, the origin of the carbon as the principal element of the woody fibre. It must be derived from other sources; and as the soil does not yield it, we are driven to look for it in the atmosphere.

Now, we have already stated that the air contains carbonic acid; and if the reason of its presence there be not, that it may yield carbon to plants, what other use can be assigned to it? Animals do not derive their chief sustenance from the air: to them pure and unmixed carbonic acid is poisonous; though taken into the stomach it is grateful. Besides, we know it to be a fact, that *during the sunshine of day* the leaves of plants are continually absorbing this very gas, and giving out oxygen; and if not for their nutrition and growth, for what other purpose? Carbonic acid being a compound of carbon and oxygen, they retain the carbon and give out the oxygen. This has been long known; but it is only a recent discovery, that the *sole* source of woody fibre is the atmosphere.

Mould, or humus, can only arise from the decay of plants. No primitive mould can have existed; for plants must have preceded the mould, which this theory assumes as necessary to their existence. Whence, then, did the first vegetables derive their carbon, if not, as now, from the surrounding air? We shall arrive at satisfactory conclusions respecting the *mode* in which animal, as well as vegetable, life and nutrition are maintained, by observing how the uninterrupted uniformity of proportion is secured in the quantities of the elements composing the atmosphere. How does it happen that, with such an immense expenditure of oxygen as occurs in the combustion of countless millions of tons of coal, and in the consumption of that gas in the lungs of the myriads of creatures that live on the earth's surface, still the composition of the atmosphere is invariably the same?

The answer to this question depends upon another. What becomes of the carbonic acid which is produced by the breathing of animals, and in every instance where a combustible body is burnt? There is no change of volume; for the oxygen extracted from the atmosphere by a coal fire is replaced by the same bulk of carbonic acid, and similarly in every breath we draw. The immense masses of carbonic acid which flow into the atmosphere from so many causes ought perceptibly, after 6000 years, to increase its quantity.

A *cause* must exist which prevents the increase of carbonic acid, by removing that which is continually forming; and there must be some means of replacing the oxygen which is removed from the air by combustion, breathing, and putrefaction.

Both these causes are united and displayed in the process of vegetable as well as of animal life. The facts we have already stated prove that the woody fibre, or carbon of plants, must be derived *exclusively* from the atmosphere. Now, carbon exists in the air only in the form of carbonic acid, and, therefore, in a state of combination with oxygen.

Besides, as already stated, carbon and the elements of water form the *principal* constituents of vegetables. Now, the proportion of oxygen in the whole mass of a plant is less than in carbonic acid. It is, therefore, certain that plants must possess the power of *decomposing* carbonic acid, since they appropriate the carbon for their own use. The formation of woody fibre, gum, starch, and the various substances containing carbon—that taken together compose a plant—must necessarily be attended with the *separation* of the carbon of the carbonic acid in the air from the oxygen of that acid. This oxygen is *returned* to the atmosphere, as experiment and observation prove, though its *source* is only just understood. And the carbon enters into composition with water, or its elements in the plant. The atmosphere must thus receive a volume of oxygen for every volume of carbonic acid which has been abstracted from it and decomposed. The leaves and green parts of a plant emit an *equal* quantity of oxygen in exchange for the carbonic acid they absorb, and they will do this even when torn from the stem on which they were just growing. Each acre of land which produces eight hundred weight of carbon, (say woody fibre,) gives annually to the atmosphere about two thousand six hundred pounds of free oxygen gas; so that an acre of meadow, wood, or cultivated land, replaces, therefore, in the atmosphere as much oxygen as is exhausted by eight hundred weight of carbon, either in its ordinary destruction by burning, or in the action of the lungs of animals.

Plants not only separate all noxious matters from the air,—they form, by this arrangement, an inexhaustible source of pure oxygen to supply that loss the air is constantly sustaining. Animals, on the other hand, throw off carbon from their lungs, which plants take in by their leaves; and thus the composition, or the relative proportions of the elements forming that medium in which they both exist, is maintained constantly unchanged.

Many conditions are necessary for the life and growth of plants. Each kind requires special conditions; and should but one of these be wanting, although all the rest be supplied, the plants will not be brought to maturity. It is in vegetable as in animal life: a mother crams her child exclusively with arrow-root; it becomes fat, it is true; but alas! it is rickety, and gets its teeth very slowly and with difficulty. Mamma is ignorant, or never thinks that her offspring cannot make bone, or, what is the same thing, phosphate of lime, the principal bulk of bone, out of starch. It does its best; and were it not for a little milk and bread, perhaps now and then a little meat and soup, it would have no bones and no teeth at all. Farmers keep *poultry ;* and what is true of fowls, is true of a cabbage, a turnip, or an ear of wheat. If we mix with the food of fowls a sufficient quantity of egg-shells, or chalk, which they eat greedily, they will lay many more eggs than before. A well-fed fowl is disposed to lay a vast number of eggs; but cannot do so without the materials for the shells, however nourishing in other respects her food may be. A fowl, with the best will in the world, not finding any lime in the soil, nor mortar from walls, nor calcareous matter in her food, is incapacitated from laying any eggs at all. Let farmers lay such facts as these, which are matter of common observation, to heart, and transfer the analogy, as they justly may do, to the habits of plants, which are as truly alive, and answer as closely to evil or judicious treatment as their own horses. The organs of plants, like those of animals, contain substances of the most different kinds. Some are formed solely of carbon and the elements of water: as, for instance, woody fibre, resin, gum, and starch; some contain nitrogen: as, for instance, the gluten of wheat; and in all plants we find metals in a state of combination with oxygen. The food which can serve for the production or increase of *any*, or of all the organs of a plant, must necessarily contain the elements of that part, or set of parts. Dogs die although fed with jelly, which contains nitrogen in abundance: they cannot live upon white bread, sugar, or starch, if these are given as food, to the exclusion of other substances. Can it be concluded from this, that these things contain no elements suited for nutrition? Certainly not.

Because a vegetable is alive, it has the power of constantly reproducing itself; for this it requires a supply of substances which contain the constituent elements of its own substance, and which are susceptible of undergoing the necessary transformation. All the organs together, whether of animal or vegetable life, have not the power to *generate*, that is, to produce out of nothing a single element. A dog would die in the vacuum of an air-pump, even though supplied with a superabundance of food; it will die in the air if no food be given to it; it will die in oxygen gas, however freely it may be supplied with nourishment. But it is not hence to be concluded, that neither flesh, nor air, nor oxygen, is fitted to support life. They are all admirably calculated to do so; so it is just as reasonable to expect to bring a plant to perfection,—wheat, for instance,—which, in its healthy and natural state, contains silica, or potash, if it be planted in a soil destitute of such inorganic materials, or to which they have not been added. When we are acquainted with the nature of a single cubic inch of that soil, and know the composition of air and rain-water, we are in possession of all the conditions necessary to their life. The source of the different elements entering into the composition of plants, cannot possibly escape us, if we know *in what form* they take up their nourishment, and compare its composition with that of the vegetable substances which compose their structure.

Vegetables undergo, after death, two processes of decomposition: one of these is *fermentation*, the other is *putrefaction*. Decaying leaves, stalks, or roots, are, in fact, undergoing a slow process, analogous to combustion; inasmuch as it is the combination of the *combustible* parts of a plant, (structures that will burn,) with the oxygen of the atmosphere.

The decay of woody fibre (the principal constituent of all plants) is accompanied by appearances of a peculiar kind. This substance, in contact with air or oxygen gas, and no longer preserved from chemical decomposition by the living principle which has now left it, unites with that gas, and the product is an equal volume of carbonic acid. The property which woody fibre in a state of decay has to form carbonic acid with the surrounding oxygen of the atmosphere, diminishes as the decay advances, till it is complete, and ceases. Mould constitutes the principal part of brown coal and peat. An atmosphere of carbonic acid, formed at the expense of the oxygen of the air, surrounds every particle of decaying vegetable matter; hence the value of ploughing, digging, and otherwise loosening the soil: it permits the access of air. An atmosphere of carbonic acid is therefore contained in every fertile soil, and is the first and most important food for the young plants before they reach the surface. The leaves of trees which fall in the forest in autumn, and old roots of grass in a meadow, are converted into what is termed humus by the same agency; but humus does not nourish plants directly, by being taken up in its unaltered state, but *by presenting a slow and lasting source of carbonic acid*, which is absorbed by the roots of plants, and forms their principal nutriment at a time when, being *destitute of leaves*, they cannot, as yet, extract food from the atmosphere: hence one reason of the value of ploughing, digging, and otherwise lightening the soil, by permitting the access of air, and consequently, of carbonic acid to the seeds and roots. Seeds should always be sown, so as to be fully exposed to the influence of the air; and one cause of the unproductiveness of cold, clayey, adhesive soils is, that the seed is coated with matter which the air cannot get at. In sandy soils, the earth is mostly sufficiently penetrable by the atmosphere; but in clayey soils, there can scarcely be too great a mechanical tearing up and division, in the process of tillage. Many ploughmen know the fact, without knowing the reason of it: however, any seed not fully supplied with air, always produces a weak and diseased plant. In this way, then, we see the true uses of the vegetable decaying mould, when well torn up by the plough. The roots perform the after-functions of the leaves: they extract from the soil the carbonic acid generated from the humus, or vegetable mould; they decompose that acid, and absorb the carbon. When a plant is quite matured, and when the organs by which it obtains food from the air are fully formed, the carbonic acid of the soil is no longer required.

If turnips be sown in a soil capable of yielding as much nourishment as they will take up, they will attain a much larger size than under the reverse circumstances. *The size of a plant is always proportioned to the* SURFACE *of the* *organs which are destined to convey food to it.* A plant gains another mouth and stomach with every new fibre of root, and every new leaf.

Let us suppose a plant fully grown. All the necessary amount of woody fibre has been formed by the leaves. But the action of the leaf does not cease. Carbon is still absorbed; the expenditure of nutriment, the supply of which continues the same, takes a new direction. The leaves now produce sugar, starch, gum, or acids, which were previously formed by the roots when these substances were necessary for the development of the stem, buds, leaves, and branches of the rising plant. The direction of the nutriment again changes, and *blossoms* are produced. The functions of most plants cease upon the ripening of their fruit, because the products of their action are no longer needed. They now yield to the chemical influence of the oxygen of the air: their feeble vitality weakly opposes the decomposition which awaits all dead matter; they change colour, fall off, and become converted into the mould of which we have been speaking.

A cubic inch of sulphuretted hydrogen gas introduced into the human lungs would cause instant death; but it is often formed, under a variety of circumstances, in the bowels without injurious effects. Each organ, whether of an animal or a vegetable, extracts from the food presented to it what it requires for its own action and sustenance; while the remaining absorbed matters, which are not nutritive, combine together, and are separated as excrement. The excrementitious matters of one organ come in contact with another during their passage through the plant or animal, and, in consequence, suffer *new transformations:* the useless matters rejected by one organ contain the elements for the nourishment of another, till what is utterly useless is expelled from the system, by contrivances for that purpose. So the kidneys, liver, and lungs, are organs of excretion: the first separate from the body substances in which a large proportion of *nitrogen* is contained; the second those with an excess of *carbon;* and the third, such as are composed, principally, of more *oxygen* and *hydrogen* than is wanted. All superabundant *nitrogen* is thrown out from the body as a LIQUID excrement through the urinary passages; all *solid* substances, incapable of further useful transformation, pass out by the intestinal canal; and all *gaseous* matters by the lungs.

The presence of life prevents common chemical decomposition or putrefaction: the power to effect the transformations essential to nutrition and growth does not belong to it. Each such transformation is owing to a disturbance in the attraction of the elements of a given compound, and is, consequently, a purely *chemical* process. Similar changes of existing compounds are in constant progress during the whole life of a plant; in consequence of which there are produced gaseous matters, thrown off by the leaves and blossoms, solid excrements deposited in the bark, and fluid soluble substances which are excreted by the roots. Through the expulsion of these matters unfitted for nutrition, the soil receives back again the greatest part of the carbon, which it had at first yielded to the young plants as food in the shape of carbonic acid, from the decaying mould.

Having disposed of the question as to the origin of *carbon* in plants, and examined the relation between vegetable mould and the springing vegetable, we must next trace the source of the *hydrogen* and *nitrogen* they contain.

All the *hydrogen* necessary for the formation of a plant or animal is supplied by the decomposition of water. From their generating wax, fats, and volatile oils, containing hydrogen in large quantity, and no oxygen, we may be certain that plants possess the property of decomposing water; because from no other body with which they are placed in contact, could they obtain the hydrogen which exists as an *element* in those matters. *The process of vegetable growth, in its simplest form, consists in the extraction of hydrogen from water, and carbon from carbonic acid.* The green resinous principle of the leaf diminishes in quantity while oxygen is absorbed. We can explain, in a similar manner, the formation of all the component substances of plants which contain no nitrogen. During the progress of growth, plants appropriate *carbon* from the carbonic acid found in the air, and *hydrogen* from the decomposition of water; the *oxygen* of which fluid is set at liberty, together with a part, or all of that contained in the carbonic acid. Decay, then, or vegetable putrefaction, is that great operation of Nature by which that oxyen which was consumed by plants during life is again returned to the atmosphere; for water is essential to such putrefaction.

As to the origin of nitrogen in plants, we may observe, that it exists in every part of the vegetable structure. No plant would attain maturity, even in the richest vegetable mould, unless *nitrogen* were supplied to it. How, it may be asked then, and in what form, does Nature furnish nitrogen to assist in the formation of vegetable albumen and gluten, to fruits and seeds?

This question is susceptible of a very simple solution. Plants, as we know, grow perfectly well in pure charcoal, if supplied at the same time—not with river or spring, or perfectly pure water, but with *rain*-water. Now, rain-water can contain nitrogen only in two forms—either as dissolved atmospheric air, (which, of course, contains nitrogen,) or as AMMONIA, of which nitrogen is *one* element. We have observed, in speaking of the composition of water, that *rain*-water is found to contain ammonia; and this is the practical application of the fact. *Pure* air may, for our present purpose, be considered as oxygen and nitrogen in certain unalterable proportions, in a state of mixture; the carbonic acid and ammonia which float in the atmosphere may be regarded as *accidental* ingredients. If we were to suppose that plants derived their nitrogen directly from the atmosphere,—that is, by depriving the air of a portion of that nitrogen which is essential to its constitution—we are met by many difficulties. Rain-water does not yield nitrogen from pure air, which it may hold in solution or suspension, but from *ammonia*, which, rising from putrefied animal remains, becomes readily dissolved in the first mass of watery vapour that may present itself. We have no reason to believe that the nitrogen of the air takes part in the processes of nutrition in plants and animals; on the contrary, we know that many vegetables emit, or give off the nitrogen which is absorbed by their roots. But, on the other hand, there are numerous facts, showing that the formation in plants of *substances* containing nitrogen, as gluten, for instance, in corn, takes place in proportion to the quantity of this element, which is conveyed TO THEIR ROOTS in the state of soluble salts of *ammonia*, derived from the putrefaction of animal matter.

All animal bodies, during their decay, yield the nitrogen, which they abundantly contain, to the atmosphere in the form of ammonia. A generation of a thousand millions of human beings is renewed every thirty years: countless millions of animals have, during that period, ceased to live. Where, but floating in the atmosphere, is the nitrogen their bodies contained during life? *Without the occurrence of putridity and the generation of ammonia, and its diffusion in the air, the wheels of nature would soon stop—vegetable and animal life could go on no longer.* Ammonia is the simplest of all the compounds of nitrogen: the reader will remember our previous statement, that hydrogen and nitrogen combine to form ammonia. Hydrogen is that element for which nitrogen possesses the most powerful affinity.

The nitrogen, then, of putrefied animals is contained in the atmosphere (combined with hydrogen) as ammonia, in the form of a gas which is capable of entering into combination with carbonic acid, and of forming a volatile salt very soluble in water. Ammonia, therefore, cannot remain long in the air, as every shower of rain must dissolve it and convey it to the earth's surface, to be absorbed and decomposed by the roots of plants. We ought to expect, and such is the fact, that *rain*-water *must at all times* contain ammonia, though not always in equal quantity. If a pint of rain-water contain only a quarter of a grain of ammonia, then a field of forty thousand square feet must receive yearly upwards of eighty pounds of ammonia, or sixty-five pounds of nitrogen; for it is ascertained that the annual fall of rain-water over this extent of surface is at least 2,500,000 pounds. This is much more nitrogen than is contained in the form of vegetable albumen and gluten in 2650 pounds of wood, 2800 pounds of hay, or 200 cwt. of beet-root, which would be the yearly produce of such a field; but it is *less* than the straw, roots, and grain of corn which *might* grow on the same surface would contain. Animal manure, as we shall presently show, acts only by the formation of ammonia. Its employment in the cultivation of grain, and of fodder for cattle, furnishes convincing proof that the nitrogen of vegetables is derived from ammonia. The quantity of gluten in wheat, rye, and barley, is very different; and they contain nitrogen in varying proportions. Even in samples of the same seed the quantity varies; and why? Evidently because one variety has been better fed with its own appropriate fertilizer, than another which has been reared on a soil less accurately adapted by artificial means for its growth. French wheat contains 12 per cent. of gluten; Bavarian 24 per cent. Sir H. Davy obtained 19 per cent. from winter, and 24 from summer wheat; from Sicilian 21, from Barbary wheat 19 per cent. SUCH GREAT DIFFERENCES MUST BE OWING TO SOME CAUSE, AND THIS WE FIND IN THE DIFFERENT METHODS OF CULTIVATION. An increase of animal manure gives rise not only to an increase in the *number* of seeds, but also to a remarkable difference in the proportion of gluten which those seeds contain. Among manures of animal origin there is great diversity. Cow dung contains but a small proportion of nitrogen. One hundred parts of wheat, grown on a soil to which this material was applied, afforded only 11 parts of gluten, and 64 of starch; while the same quantity of wheat, grown on a soil fertilized with *human urine*, yielded 35 per cent. of gluten, and of course a smaller proportion of less valuable ingredients. During the putrefaction of urine, ammoniacal salts are formed in large quantity, it may be said, exclusively; for under the influence of warmth and moisture, urea, the most prominent ingredient of urine, is converted into carbonate of ammonia. Putrid urine is employed in Flanders as a manure with the best results. The barren soil on the coast of Peru is rendered fertile by means of a manure called Guano, which is collected from several islands in the South Sea. It forms a layer several feet in thickness upon the surface of these islands, and consists of the putrid excrements of innumerable sea-fowl that remain on them during the breeding season. This substance has recently been imported in large quantities into England; and its fertilizing powers are very extraordinary. Its price, about £18 per ton, is a serious objection; and since the nitrogen it contains forms its principal recommendation, doubtlessly other matters nearer home will not be wasted, or their value unknown and disregarded, as to a great extent they have been. As to the practical results of the application of Guano, an intelligent agriculturist in the neighbourhood of Hamburg has forwarded the annexed remarks to the Editor of the *Gardener's Chronicle.* He observes that "Most of the experiments with guano in the vicinity of this city have been made on meadows and lawns. On these it has produced the best possible effects; so that, for instance, at Flottbeck, the patches manured with guano presented not only a finer and darker green, but the grass was closer and more rich; so that, comparing it with patches not guanized, the produce of the former may, without exaggeration, be stated to be double. To give an idea of the extraordinary forcing qualities of guano, we may mention that at Flottbeck, on a spot of grass managed after the English fashion, the second cutting of the grass was necessarily five days after the first, while the grass growing close by, (which had not been guanized,) although healthy and vigorous, required double the time to arrive at the same state of progress. It deserves to be stated as something remarkable, that on the guanized spot, the dew appeared in the morning much stronger on the tops of the leaves, than on the part unguanized. In an experiment made by M. Staudinger on a barren hill, composed of granite or quartz, the guanized spot exhibited a dark bluish green sward, while round about nothing but barrenness was to be seen. If, therefore, a land owner wishes to cover bleak hungry pasture in a short time with nutritious grass for cattle or sheep, the guano certainly is the thing to do it. It would not only produce a plentiful fodder in the autumn, where cattle can be well nourished and prepared for the winter, but such guanized pasture will bring a heavy crop early in the spring. Guano has also been used advantageously on a sour meadow overgrown with horsetails; and it produced, instead of reeds and bullrushes, a dense turf of sweet grass, and the horsetail almost disappeared. Thus, in the first place, more grass is obtained, which may be put down as double the former crops; and then the grass is very much improved in quality. Of course good drainage must be attended to on each meadow, if the result is expected to be complete. In using guano we must be careful to pulverize it well; because, on account of its tenacity, it will form into lumps, and on places where it lies too thick, it will burn the grass, although, subsequently, even on such places a luxuriant herbage will spring up. Experiments with guano on spring crops have been as successful at Flottbeck, with both wheat and rye, as on the above meadow. The wheat manured in the spring with guano is much superior to that manured in the ordinary way, both in grain and straw. The following experiment was tried on a spot of almost blowing sand:—'On the 18th March, several square rods in the above locality, planted with winter rye, were strewed with guano. The spot thus manured was in a short time not only conspicuous for its dark green colour, but the tiller became so luxuriant as to cover the whole surface. Notwithstanding a drought of two months, the guanized crops remained in the same flourishing condition; whilst the other rye standing close by had a weak and sickly appearance. Subsequently the former attained the height of five or six feet, with ears five inches long, with strong plump grain; whilst the latter were scarcely half that height in straw, and their ears were barren and empty.' This experiment speaks in favour of guano in preference to other manure in another respect. If a light sandy soil like the above is manured too much with common dung, and if there follows a luxuriant vegetation, with dark green foilage, we may be sure that, if there be subsequently any long drought, or sudden change of temperature from great heat to intense cold, rust will follow as a matter of course; whilst, in the above experiment, notwithstanding a nine-weeks' drought, and some intervening night frosts, the growth of the guanized rye was uniformly good up to the ripening of grain—a sufficient proof that the guano must possess the property of attracting and retaining the fine vapour contained in the air. Hence the fact is to be explained why dew was more apparent on the guanized turf than on that not subjected to that process. As we know that, in general, during long drought, the action of dung—in fact of every manure—ceases; and as it is light sandy soil which first suffers from drought, it must be evident what valuable manure guano is, not only on pastures, but for winter rye, our chief crop on light land. If an acre of land is dressed with 125 lbs. of guano, an abundant crop of grain and straw will fully repay the expenses incurred. If such a rye-field is laid down in spring with meadow catstail grass (*Phleum pratense*) and white clover, a heavy grass crop in the autumn would still increase the advantages already mentioned. As rape can by no means be too luxuriant, guano would produce an extraordinary result on it."

If a soil consist only of sand and clay, and be deficient of organic matter or the decaying remnants of animal or vegetable life, it is sufficient, and chemically correct, to add to it guano, in order to ensure a plentiful crop. Guano consists of ammonia in separate combination with uric, phosphoric, oxalic, and carbonic acids, together with a few earthy salts and some impurities. If guano be the fertilizer employed, it is valuable, chiefly from the ammonia it contains, and ammonia is valuable because one of its elements is nitrogen, which is yielded to the plants. Ammonia assists not only in the formation of gluten in wheat, but also in the production of vegetable albumen, one of the principal constituents of plants, and it is ammonia which forms the red and blue colouring of flowers. Nitrates, that is, earthy or metallic substances, combined with nitric acid, (which nitric acid is itself a compound of nitrogen and oxygen,) are necessary constituents of several plants which thrive only when ammonia is present,—hence the value of nitrate of soda. The influence of the dried rays of the sun is to effect the disengagement of oxygen from the stem and leaves of plants, (as previously stated,) which oxygen, seizing upon the nitrogen contained in ammoniacal matters, forms nitric acid, found in union with certain bases in many vegetables. In this way ammonia, by its transformation, furnishes nitric acid to the tobacco plant, that is, if it be found growing in a soil completely free from nitre or saltpetre, which is not nitrate of soda, but, in chemical language, nitrate of potass. The urine of men and of animals living upon flesh contains a large quantity of nitrogen, partly in the form of phosphates, partly as *urea*, a substance naturally peculiar to urine. Urea is transformed by the putrefactive process into carbonate of ammonia; that is to say, it takes the form of the identical salt which is always present in rain-water. *Human urine is the most powerful manure for all vegetables which contain nitrogen; that of horses and horned cattle contains less of this element, but infinitely more than the solid excrements of these animals.*

In the face of such facts as these, is it not pitiable to observe how the urine of the stable or cowshed is often permitted to run off, to sink uselessly into the earth, or to form a pool in the middle of a farm-yard, from which, as it putrefies, the ammonia formed in it is rapidly and completely escaping into the atmosphere, to be of as great utility in that volatile form to a neighbour's acres as to those nearer home ?

It should be the care of the farmer so to employ all the substances containing nitrogen which his farm affords in the shape of animal excrements, that they shall serve as nutriment to his own fields. This will not be the case unless they are properly preserved and distributed over the soil. A heap of manure lying unemployed would serve him no more than other people, if the nitrogen it contains be allowed to form ammonia, by combining with hydrogen. All animal matters emit carbonic acid and ammonia as long as any nitrogen remains in them. The residue is a nearly worthless carbonaceous mass. All animal excrements emit carbonic acid and ammonia as long as nitrogen exists in them. In every stage of their putrefaction an escape of ammonia from them may be induced by moistening them with pearl-ashes dissolved in water, the ammonia being apparent to the senses by its pungent effect on the nostrils. This ammonia evolved from manure is imbibed by the soil either in solution in water, or in the form of gas; and thus it is that plants may artificially be made to receive a larger supply of nitrogen than is naturally afforded to them by the surrounding atmosphere. Cultivated plants receive, of course, the same quantity of nitrogen from the air as trees, shrubs, and wild plants; but this, of course, is not enough for the purposes of agriculture; cabbages, wheat, potatoes, and apples being very different things in their wild, or, more properly, their *natural* state. The object of forest culture is, the production of carbon or woody fibre; of garden or field culture, chiefly the addition of as much nitrogen as the plant can be made to take up.

The solid excrements of animals do not contain as much nitrogen as those which are voided in a liquid form; and, for this reason, do not constitute so powerful a fertilizing material. This could not be otherwise. The *quantity* of food which animals take, diminishes or increases in proportion as it contains more or less of the substances containing nitrogen. The bowels of the cow are *relatively* much longer than those of the tiger; the *bulk* of food consumed by the former animal is greater, and it requires to be retained longer, to traverse a greater extent of surface, before it can yield all its nutriment, than occurs in animals feeding on flesh, which contains so much nitrogen. A horse may be kept alive upon potatoes, which contain very little nitrogen; but life thus supported is gradual starvation. So the *quantity* of rice which an inhabitant of the East Indies will eat astonishes an Englishman; but the fact that rice contains *less* nitrogen than any other kind of grain, at once explains the circumstance. In hot countries human beings live sparingly on vegetables which contain little of this principle; in very cold countries, human beings require very fat substances, in order to support existence, and to enable them to generate as much animal heat as is necessary. The Esquimaux will devour amazing quantities of whale's blubber, and would speedily die (in that climate) without a free supply of food containing large quantities of nitrogen. Hence, vegetation is scanty—for food it is scarcely necessary: they live upon fish, or animals caught in the chase. In tropical climates, on the contrary, where animal food is not so necessary, a luxuriant vegetation is provided to satisfy the natural wants of man.

By means of manure an *addition* only is made to the nourishment supplied from the air; for the excrements of all animals contain less nitrogen than their food, and consequently a smaller quantity of matter containing nitrogen is given to the soil than has been abstracted in the form of grass, hay, or seeds.

Another reason why liquid excrements containing ammonia (or that which, by further spontaneous chemical action yields ammonia, and consequently nitrogen) are more useful than solid excrements, is to be found in the fact, that the former contain the greatest part of their ammonia *in the state of salts:* in a form, therefore, in which *it has lost its volatility* when presented in this condition, not the smallest *quantity of ammonia*, in such a shape, *is lost to the plants*,—it is all dissolved by water and *imbibed by their roots.* Practical farmers see the results: they know that plaster of Paris or gypsum, the insoluble sulphate of lime, strikingly increases the luxuriance of meadow grass upon which it is strewed. But why? Because it fixes in the soil all the ammonia of the atmosphere, which would otherwise be *partially* volatilized with the water that constantly evaporates from the surface of the soil. The sulphuric acid of the sulphate of lime has a stronger affinity for ammonia than it has for lime; so *sulphate* of *ammonia* is formed, which is not volatile, does not escape into a neighbour's pastures. In such an instance, the carbonate of ammonia *naturally* contained in rain-water is decomposed by the gypsum, in precisely the same manner as occurs in the manufacture of sal-ammoniac. Soluble (but not volatile) sulphate of ammonia, and carbonate of lime or chalk, are formed by double decomposition; so that the beneficial effects of gypsum as a manure are not direct, but indirect, by *fixing* the ammonia either of rain-water or of manure with which it may have been mixed, and thus presenting that ammonia, or its valuable element nitrogen, to the roots of plants in a form susceptible of absorption. All the gypsum gradually disappears, but its action upon the carbonate of ammonia continues as long as a trace of it exists.

It is quite evident, therefore, that science alone can truly explain the mode in which certain matters exert their beneficial agency; and consequently science alone can *rationally* direct the practical farmer. All else beside is mere experiment,—hazardous, expensive, and conjectural.

In order to form an idea of the effect of gypsum, it may be sufficient to remark, that 100 pounds of burnt gypsum *fixes* as much ammonia in the soil as 6250 pounds of horses' urine would yield to it. The decomposition of gypsum does not take place instantaneously; it proceeds very gradually, and this explains why the action of gypsum lasts for several years; the supply of ammonia from the air, of course, remaining steady and unfailing.

All rust of iron (or iron in combination with oxygen) contains a certain quantity of ammonia: the advantage of manuring fields with burned clay depends upon the presence of oxide of iron. Now, all minerals containing alumina, or oxide of iron, possess, in a remarkable degree, the property of attracting ammonia from the atmosphere, and of retaining it in the soil. Pipe-clay, (which is aluminous earth,) when moistened with a solution of caustic potash, emits ammonia, which it has absorbed from the atmosphere Soils, therefore, containing oxides of iron, and burnt clay, must absorb ammonia, which is separated by every shower of rain, and conveyed, in a dissolved state, to the roots of vegetables. Charcoal possesses a similar action; it will absorb ninety times its volume of ammoniacal gas, which may again be separated simply by moistening it with water, in which ammonia is extremely soluble. This explains why plants will grow in pure charcoal moistened with RAIN-water. We have here another easy and satisfactory method of explaining still further the properties of humus, or of wood in a decaying state. Decayed oak-wood absorbs 72 times its weight of ammonia; humus, then, is not only a slow and constant source of carbonic acid, (repairing the loss of that which is constantly decomposed and absorbed by the leaves of vegetables, as before stated,) but it is a means by which the necessary nitrogen is *mechanically* conveyed to plants.

No conclusion can have a better foundation than this, that it is the ammonia of the atmosphere which furnishes all the nitrogen to plants they receive while uncultivated. All the innumerable products of vitality resume, after death, the original form from which they sprung; and thus death, the complete dissolution of an existing generation of animals and plants, becomes the source of life for a new one, and of that *artificial* and *forced* amount of nutriment which plants may be *compelled* to receive, if *judiciously* fed, or, in other words, manured.

CHAPTER VI.

Of the Sources of the Saline, Earthy, and other Unorganized Constituents of Vegetables.

A further question arises: Are the conditions already considered all that is necessary for the life and growth of plants? It will now be shown that they are not.

Carbonic acid, water, and ammonia, are necessary for the existence of vegetation, because they contain the *elements* from which their organs are formed; but other substances are requisite (as silica in straw) for the formation of certain organs destined for special functions peculiar to each family of plants. Plants obtain these substances from inorganic nature. In the ashes of burnt vegetables the same substances are found, although in an altered condition.—Many of these inorganic constituents vary according to the soil in which the plants grow; but without a certain number of them, according to the nature of such plant, they never arrive at maturity. All substances that water will dissolve in a soil are absorbed by the roots of plants exactly as a sponge imbibes a liquid indiscriminately. The substances thus conveyed to plants, are either retained in greater or less quantity, or are entirely separated when not suited for nutritive purposes.

Phosphate of magnesia, in combination with ammonia, is an invariable constituent of the *seeds* of all kinds of grasses. It is contained in the outer husk, and is introduced into bread, along with the flour, as part of the bran. When ammonia is mixed with beer, this salt is precipitated.

Most plants contain ACIDS of very different composition and properties, all of which are in combination with bases, such as potash, soda, lime, or magnesia. These bases evidently regulate the formation of the acids; for example, the quantity of potash contained in the juice of the grape is less when it is ripe than when unripe; and the acids, under the same circumstances, are found to vary in a similar manner. We glanced, in a former section, at the *existence* of inorganic acids and bases in vegetables: we have now to investigate their *source.*

The *acids* found in the different families of plants are very various. It cannot be supposed their presence and peculiarities are the result of chance or accident. They must serve some end in vegetable life, independently of their utility to the animals for whose healthful use some, if not all, of them are ultimately destined. Acids constantly exist in vegetables; and it is incontestable that they are necessary to their life. And it is equally certain that some alkaline, earthy, or metallic base, is also indispensable, in order to enter into combination with such acids which are always found in the state of salts, as oxalate of potash in the sour-leaf or sorrel.

The nature of a soil exercises a decided influence on the quantity of the different metallic oxides contained in the plants which grow on it. It is not known *in what form* silica, manganese, and oxide of iron, are contained in vegetables; but we know that potash, soda, and magnesia, can be extracted from *all* parts of their structure, in the form of salts of organic acids. As these acids and bases are never absent from plants, and as even the form in which they present themselves is subject to no deviation, it may be affirmed that they are necessary, as exercising an important influence over the development of fruits and seeds, and also on many other functions, of the nature of which we are at present ignorant. The *perfect* development of a plant is dependent, then, on the presence of alkalies, or alkaline earths; when these substances are totally wanting, its growth will be stopped; when they are only deficient, it must be correspondingly impeded. Firs and pines find a sufficient quantity of alkalies in barren, sandy soil; and wheat thrives in another kind of soil: because the bases necessary to bring each to maturity exist there in sufficient quantity. The proportion of silicate of potash (necessary for the firmness of wheat straw) does not vary perceptibly in the soil of corn-fields, because what is removed by the reaper, is again replaced in putrefying straw. But this is not the case with meadow-land. Hence we never find a luxuriant crop of grass on sandy and limestone soils which contain little potash, evidently because one of the constituents indispensable to the growth of the plants is wanting. If a meadow be well manured, we remove, with the increased crop of grass, a greater quantity of potash than can, by a repetition of the same manure, be restored to it. So, grass-land manured with gypsum soon ceases to feel its agency. But if the meadow be strewed from time to time with wood ashes, or soap-boilers' ley made from wood ashes, then the grass thrives as luxuriantly as before. And why? The ashes are only a means of restoring the necessary potash for the grass stalks. So oats, barley, and rye, may be made for once to grow upon a sandy heath, by mixing with the scanty soil the ashes of the heath-plants that grow upon it. Those ashes contain soda and potash, conveyed to the growing furze or gorse by rain-water. The soil of one district consists of sandstone; certain trees find in it a quantity of alkaline earths sufficient for their own sustenance. When felled, and burnt, and sprinkled upon the soil, oats will grow and thrive that without such aid would not vegetate.

The most decisive proof of the absurdity of the indiscriminate use of any strong manure was obtained at Bingen, a town on the Rhine, where the produce and development of vines were highly increased by manuring them with animal matters, such as shavings of horn. After some years, the formation of the wood and leaves decreased perceptibly. Such manure had too much hastened the growth of the vines: in two or three years they had exhausted the potash in the formation of their fruit leaves and wood; so that none remained for the future crops, as shavings of horn contain no potash. Cow-dung would have been better, and is known to be better. A knowledge of chemistry furnishes the reason, which is found in the fact, that it contains a large proportion of potash, though very little nitrogen. Hence, if nitrogen be the element in demand, cow-dung is *not* the material that will yield it. All the potash contained in the food consumed by a cow, is again immediately discharged in its excrements.

A landed proprietor, in order to obtain more potash for his soil, planted it with wormwood, the ashes of which are well known to contain a large quantity of that alkali. The consequence was, that he rendered his land quite incapable of bearing grain for many years. He had entirely deprived the soil of its potash. Had he sown wheat upon it instead of wormwood, he would have found the soil contained as much potash as was necessary for the nutrition of *that* vegetable. The supposition that alkalies, metallic oxides, or inorganic matter in general, are *produced* by plants, is refuted by such facts as these: they are *absorbed* by plants, not *generated*.

Those grasses, the seeds of which furnish food for man, follow him like the domestic animals. Saline plants require common salt, and seek the sea-shore. The plants which grow on dung-hills need ammonia and the nitrates, and are attracted whither these can be found, just as the dung-fly is to animal excrements. So, likewise, none of our corn plants can bear plump seeds, yielding good and plentiful flour, without a large supply of phosphate of magnesia and ammonia, substances which they require for their maturity. No soil is richer in them than those where men and animals dwell together. Where the urine and excrements of these are found, corn plants appear; because their seeds cannot attain maturity unless supplied with the constituents of these matters.

During the boiling or evaporation of saltpetre ley, the salt volatilizes with the water, causing a loss which otherwise could not be explained. In sea storms, leaves, in the direction of the wind, are covered with crystals of salt, twenty or thirty miles from the sea. The great storm which occurred in England a few winters ago, verifies this statement. But it does not require a storm to cause the volatilization of the salt: every breeze must carry it away. The sea-air is always sufficient to make a solution of nitrate of silver turbid and milky. Now, as millions of tons of sea-water annually evaporate into the atmosphere, a corresponding quantity of the saline matters dissolved in it, common salt, muriate of potash, muriate of magnesia, and other matters, will be conveyed by the wind to the land. This volatilization is a source of considerable loss in salt-works where the quantity of salt in the liquor is not large.

According to Marcel, sea-water contains in every 1000 parts 26 of common salt, 4 of sulphate of soda, or glauber salt, 1½ of muriate of potash, 5¼ muriate of magnesia, and 1½ of sulphate of lime or gypsum. If it be asked, whether there be any peculiarities in the mode of existence of sea-plants and fish, we know that ammonia is found in sea-water; and that, while *air* contains only from four to six ten-thousandth parts of its volume of carbonic acid, *sea-water* contains 100 times more, or 620 parts in every ten thousand; so that the same conditions which sustain living beings on the land, are combined in the ocean, in which a separate world of other plants and animals exists.

By the continual evaporation of the sea, its salts are spread over the whole surface of the earth, subsequently to be carried down by the rain, and furnishing to vegetables, through the medium of the soil, those saline matters essential to their existence. The salts of potash, magnesia, and soda, are not peculiar to the ocean: they are found naturally existing on the land as in the water; but the above explanation accounts for the origin of alkalies in the ashes of plants in those cases where the soil could not have yielded them. Nor must we overlook the fact, that whatever be the nature of the soil, or however impoverished by successive crops of alkaline vegetables, upon that surface the distant ocean is for ever, unchangingly, and silently, pouring the saline treasures of the great deep. Were the proportions of land and ocean reversed as to their extent, it is easy to predict the effect upon vegetation; as it is, the existing quantity of saline material in the ocean (which could not be increased without detriment to its inhabitants) is amply sufficient for the more than single purpose that wise arrangement was destined to answer. The atmosphere contains only a thousandth part of its weight of carbonic acid; and yet, small as this proportion appears, it is quite sufficient to supply the whole of the present generation of living beings with carbon for a thousand years, even if it were not renewed. Navigators have sailed for hundreds of miles along the unbroken edge of a coral reef: the clustering islands of the Pacific are many of them exclusively of coraline origin. Sea-water contains one twelve-thousandth part of its weight of lime; and yet, from this apparently minute quantity, insect agency has raised those very reefs upon which many a huge ship has been dashed into shapeless fragments.

CHAPTER VII.

Of the necessary Relation between the Composition of a Soil and the Vegetables it is fitted to raise. Fallowing and Green Crops considered as Vegetable manure.

The methods employed in the cultivation of land are different in every country; and when we inquire the cause of these differences, we are told that they "depend upon circumstances." Now, as few people have endeavoured to ascertain these circumstances, to reason correctly, and act from rational principle, no answer could show ignorance more plainly. So, when we inquire how manure acts, we are either met with a reply that is figurative and incorrect, or, with the admission that the result is all that is known or cared about. We are told that the excrements of man and animals, or, that certain mineral matters are supposed to contain an incomprehensible *something*, which assists in the nourishment of plants, and increases their size. No attempt is made to ascertain the component parts of the different species of manure, much less to ascertain whether it be precisely fitted to supply a known deficiency in the soil.

Besides heat, light, moisture, and the component elements of the atmosphere, which are necessary for the *mere existence* of all plants, certain fertilizing substances are seen to exercise a peculiar influence over the development either of whole plants, or of particular parts of them. Such substances are either already contained in soil, or may be artificially supplied in the form of manure.

The rules of a rational system of agriculture should enable us, therefore, to give to each plant that which it requires for the attainment of the *special* object in view —namely, an *artificial increase of certain parts* which are employed as food for man and animals.

The means employed for the production of fine pliable *straw* for hats and bonnets is the *very opposite* to the mode which must be adopted, in order to produce the largest possible quantity of *corn* from the same plant. Peculiar methods must be used for the production of nitrogen in the seeds; others for giving strength to the straw; and others again, when we wish to give such qualities to the straw as will enable it to bear the weight of the ears.

We must proceed in the artificial rearing and forcing of plants precisely as we do in the fattening of animals. The flesh of wild animals is devoid of fat, or nearly so. The production of flesh and fat may be artificially increased: all domesticated animals are easily fattened. To do this, we add to the quantity of food, and lessen (as in the stall-fed ox) the waste occasioned by the increased action of the lungs, (as consequent upon motion,) together with the waste which such muscular exertion would produce by increased action of the skin.

Arable land is originally formed by the crumbling of rocks, and its properties depend on the nature of its component parts.

Sand, *clay*, and *lime*, are the names given to the principal constituents of the different kinds of soil.

Pure sand, and pure limestone, in which there are no other unorganized substances except the earth of flint, chalk, or silicic acid combined with lime, form absolutely barren soils. But clay always forms a part of fertile soils. Whence is the origin of clay earths in arable land? What are their constituents? and what part do they play in favouring vegetation? They are produced by the breaking down of *aluminous minerals* by the action of the weather. These minerals are found, mixed with other substances, in granite, mica-slate, porphyry, clay slate, the volcanic rocks, and others. Mountain limestone is remarkable for the quantity of clayey earths which it contains. In grauwacke we find pure quartz, clay slate, and lime; in the sandstones, quartz and loam; and in the transition limestone there is an intermixture of clay, felspar, and clay slate. These examples may be sufficient.

It is known that aluminous minerals (that is to say, minerals containing the metal "*aluminium*," which, combined with oxygen, forms "*alumina*," or the pure earth of clay) are the most widely diffused on the surface of the earth; and all *fertile* soils, or soils capable of culture, invariably contain alumina.

There must, therefore, be something in *aluminous earth* which causes it to exercise an influence on the life of plants, and to assist in their growth. The property on which this depends is, that *clay invariably contains potash and soda*. Besides which alumina attracts and retains water and ammonia from the atmosphere. Alumina is itself very rarely found in the ashes of plants; but silica (or the earth of flints) is always present, having in most places, entered the plants by means of alkalies. Among aluminous minerals, felspar, which is one of them, contains 17 per cent. of potash; mica from 3 to 5 per cent. of soda: clay slate contains from 2 to 3 per cent. of potash; and loam from $1\frac{1}{2}$ to 4 per cent. of the same alkali.

So that, in a layer of soil formed by the breaking down of 40,000 square feet of one of these rocks, to the depth of 20 inches, we should find that so much felspar would contain more than a million pounds of potash; if the soil were formed by the disintegration of clay slate, about 200,000; if loam were the material, from 87,000 to 300,000; and similarly of other rocks of partially aluminous character.

Potash is present in all clays, and in marl; it has been found in all aluminous earths in which it has been sought. Alum (which is a sulphate of alumina, combined with sulphate of potash) may be procured by digesting clay in sulphuric acid, which takes up both the alumina and the potash.

A thousandth part of loam mixed with the quartz in red sandstone, or with the lime in the different limestone formations, affords as much potash to a soil twenty inches in depth as is sufficient to supply a forest of pines growing upon it with potash for a hundred years.

Water, impregnated with the carbonic acid of the atmosphere, decomposes rocks which contain alkalies, and then dissolves a part of the alkaline carbonates formed in the process. Plants also, by producing carbonic acid during their decay, and by means of the acids emitted by their living roots, contribute no less powerfully to destroy the coherence of solid minerals. Air, water, and changing temperature prepare the different species of rocks for yielding to plants the potash or soda they contain. Mrs. Ellis relates, that among the mountains which divide France from Spain, the rocks actually *smoke* after rain, under the influence of the summer sun, and become so hot that it is uncomfortable to sit down upon them. Changing temperature is a most important agent in nature. It not only assists in the *original formation* of soils, but exerts a most powerful influence over those already in existence. In *wet* soils the temperature rises slowly, and never attains the same height as in one that is sandy and dry. When the heat of the atmosphere rises no higher in the shade than 60 or 70 degrees, a *dry* soil may become so warm as to raise the thermometer to 90 or 100. Hence, though the expression be used figuratively, it is in this instance strictly correct to say that *wet* soils are *cold.*

The *exhaustion of alkalies* in a soil by successive crops is the true reason why practical farmers *suppose* themselves *compelled* to suffer land to lie fallow. It is the greatest possible mistake to think that the temporary diminution of fertility in a field is chiefly owing to the loss of the decaying vegetable matter it previously contained: it is principally the consequence of the exhaustion of potash and soda, which are restored by the slow process of the more complete disintegration of the materials of the soil. It is evident that the careful tilling of fallow land must accelerate and increase this further breaking up of its mineral ingredients. Nor is this repose of the soil always necessary. A field, which has become unfitted for a certain kind of produce, may not, *on that account,* be unsuitable for another; and upon this observation a system of agriculture has been gradually formed, the principal object of which is to obtain the greatest possible produce in a succession of years, with the least outlay for manure. Because plants require for their growth different constituents of soil, changing the crop from year to year will maintain the fertility of that soil (provided it be done with judgment) quite as well as leaving it at rest or fallow. In this we but imitate nature. The oak, after thriving for long generations on a particular spot, gradually sickens; its entire race dies out; other trees and shrubs succeed it, till, at length, the surface becomes so charged with an excess of dead vegetable matter, that the forest becomes a peat moss, or a surface upon which no large tree will grow. Generally long before this can occur, the operation of natural causes has gradually removed from the soil substances essential to the growth of oak, leaving others favourable and necessary to the growth of beech or pine. So, in practical farming, one crop in artificial rotation with others, extracts from the soil a certain quantity of necessary inorganic matters; a second carries off, in preference, those which the former had left, and neither could nor would take up.

Experience proves that *wheat* should not be attempted to be raised *after wheat* on the same soil; for, like tobacco, it *exhausts* the soil. But, if "humus," decaying vegetable matter, gives it the power of producing corn, how happens it that, in soils formed in large proportion of mouldered wood, the corn-stalk attains no strength, and droops permanently? The cause is this; the strength of the stalk is due to *siliciate of potash*, and the corn requires *phosphate of magnesia;* neither of which substances a soil of decaying vegetable matter can afford, since it does not contain them: the plant may, indeed, under such circumstances, become an herb, but it will bear no seeds. We say phosphate of magnesia is necessary;—the small quantities of the phosphates found in peas and beans is the cause of their *comparatively* small value as articles of nourishment, since they surpass all other vegetable food in the quantity of *nitrogen* they contain. But as the component parts of bone, namely phosphate of lime and magnesia, are absent in beans and peas, they satisfy appetite without increasing the strength.

Again, how does it happen that wheat does not flourish on a sandy soil, and that a limestone soil is also unsuitable, unless mixed with a considerable quantity of clay? Evidently because these soils do not contain potash and soda, (always found in clay;) the growth of wheat being arrested by this circumstance, even should all other requisite substances be presented in abundance. It is because they are mutually prejudicial by appropriating the alkalies of the soil, that wormwood will not thrive where wheat has grown, nor wheat where wormwood has been.

One hundred parts of wheat straw yield 15½ of ashes; the same quantity of barley straw, 8½; of oat straw, only 4: the ashes of the three are, chemically, of the same composition. Upon the same field which will yield only one harvest of wheat, two successive crops of barley may be raised, and three of oats. We have, in these facts, a clear proof of what is abstracted from the soil, and, consequently, what plants require for their growth,—a key to the *rational* mode of supplying the deficiency.

Potash is not the *only* substance requisite for the existence of most plants; indeed it may be replaced, in some cases, by soda, magnesia, or lime; but other substances are required also.

Plants obtain *phosphoric* acid (found in combination with lime or magnesia) from the soil, and they, in their turn, yield it to animals, to assist in the formation of their bones. Creatures that feed upon flesh, bread, fruit, and husks of grain, take in much more phosphorus than is required for rhe building up of the animal fabric; and this excess is again usefully thrown out by them, chiefly in their liquid excrements. Some plants, however, extract other matters from the soil besides *silica*, *potash*, and *phosphoric acid*, which are essential constituents of the plants ordinarily cultivated.

English farming presents us with varied instances of plants sown, and growing together in the same field. Two such vegetables will mutually injure each other, if they withdraw the same food from the soil. Plants will thrive beside each other, either when the substances necessary for their growth, extracted from the soil, are of different kinds, or when they themselves are not both in the same stage of growth at the same time. On a soil containing potash, wheat and tobacco may be reared in succession, because the latter plant does not require the phosphates which the wheat has appropriated to itself. Now, tobacco requires only alkalies, and food containing nitrogen. When we grow different plants in the same soil, for several years in succession, the first of which leaves behind that which the second, and the second that which the third may require, the soil will be a fruitful one for all the three kinds of produce. If the first plant, for example, be wheat, which consumes the greatest part of the silicate of potash in the soil, the plants which succeed it should be such as require little potash, as turnips or potatoes. The wheat lands may be sown again with wheat, advantageously, after the fourth year. The reason of this is, that during the interval of three years, the soil will, *by the action of the atmosphere,* be rendered capable of again yielding silicate of potash in sufficient quantity for wheat. Whether this process can be *artificially anticipated,* by supplying the exhausted ingredient to the soil, is a further, and most interesting inquiry.

In a four-years' course of cropping, the crops gathered amounted, per acre, to—

1st year, *Turnips*, 25 tons of bulbs, and 7 tons of tops.
2d year, *Barley*, 38 bushels, and a ton of straw.
3d year, *Clover* and *Rye Grass*, 1 ton of each in hay.
4th year, *Wheat*, 25 bushels, and 2 tons of straw.

Supposing none of the crops to be eaten upon the land, the quantity of *inorganic matter* contained in the above would be as follows:—

	lbs.		lbs.	
Potash,	281	Silica,	318	
Soda,	130	Sulphuric acid,	111	in combination with the earths and alkalies ;
Lime,	242	Phosphoric acid,	61	
Magnesia,	42	Chlorine,	39	
Alumina,	11			

making a gross weight of 1240 pounds, or about eleven hundred weight.

A still clearer idea of the importance and quantities of these inorganic matters, may be obtained by a consideration of the fact, that if we were to carry off the entire of the above produce, and return none of it again in the shape of manure, (supposing also that we could stop the beneficial agency of the atmosphere during that period,) we must, or ought, instead of that produce,—if the land is to be restored to its original condition,—add to each acre, every four years, 300 pounds of pearl ashes, or potash ; 440 of carbonate of soda; 65 of common salt; 240 of quick lime; 250 of sulphate of magnesia, that is, Epsom salts; 84 of alum; and 260 of bone dust: making 1729 pounds of solid saline matter, at an expense of nearly £9. The fertility of a soil cannot remain long unimpaired, unless we replace in it all those substances of which it has been deprived. We could keep our fields in a constant state of fertility, by replacing, every year, as much as we remove from them in the form of produce; and, be it remembered, that our cultivated corn plants, and bulbous roots, are not like forest plants and trees: the quantity of nutriment they require, and take up, to bring them to perfection and perpetuate the race, is far more than the unaided elements around them could supply. Wheat, for instance, as a natural production of the soil, appears to have been a very small grass: and the case is still more remarkable with the apple and the plum. The common crab seems to have been the parent of all our apples. Potatoes and turnips, in their wild or natural state, are unfit for food; and two fruits can scarcely be conceived more different in colour, size, and appearance, than the wild plum and the rich magnum bonum. We have to contend, then, with two important differences: *First*, That wheat or turnips are *not* natural productions; and, *secondly*, That because they are not, they drain or exhaust unassisted soil faster than the wild plants of the forest; nor will they thrive long, if denied that assistance from artificial nutriment, which nature cannot supply in sufficient quantity.

It is evident, then, that an *increase* of fertility, and consequent increase of crop, can only be expected when we add more to the soil of the *proper* material, (*and no other*,) than we take away. Any soil will partially regain itself by lying fallow: this is owing to atmospheric action, and the conversion of the roots and stalks into humus. But though the quantity of decaying vegetable humus in a soil may be increased to a certain degree by cultivation and alternate cropping, still there cannot be the smallest doubt, that a soil must (without help) ultimately lose those of its constituents, which are removed in the seeds, roots, and leaves of the plants raised upon it.

To prevent this loss, and, as a further object, to enable us to raise increased quantities of productions, demanding more sustenance than the land will naturally yield, is the object of the application of the various substances used as MANURES. They will prove useless, injurious, or valuable, precisely as they are accurately or inaccurately adapted to meet the deficiency.

Land, when not employed in raising food for animals or man, should, at least, be applied to the purpose of raising manure for itself; and this, *to a certain extent*, may be effected by means of GREEN CROPS, which, by their decomposition, not only add to the amount of vegetable mould contained in the soil, but *supply the alkalies that would be found in their ashes.* That the soil should become richer by this burial of a crop, than it was before the seed of that crop was sown, will be understood by recollecting that *three-fourths* of the whole organic matter we bury *has been derived from the air:* that by this process of ploughing in, the vegetable matter is more equally diffused through the whole soil, and therefore more easily and rapidly decomposed; and that by its gradual decomposition, ammonia and nitric acid are certainly generated, though not so largely as when animal matters are employed. He who neglects the green sods, and crops of weeds that flourish by his hedgerows and ditches, overlooks an important natural means of wealth. Left to themselves, they ripen their seeds, exhausting the soil, and sowing them annually in his fields: collected in compost heaps, they add materially to his yearly crops of corn. We have said that absolute repose of the soil is not frequently needed; and, with some practical illustrations of the system of alternate cropping, we will close this section.

In Flanders, two crops of clover are cut, and the third is ploughed in. In Sussex, turnip seed has been sown at the end of harvest, and, after two months, again ploughed in with great benefit to the land. So turnip leaves and potato tops decay rapidly, and are more enriching when buried in the green state. In the Earl of Leicester's course of cropping, the land is never idle. The turnip is the first in the order of succession. This crop is manured with recent dung, which immediately affords sufficient matter for its nourishment; the heat produced in its decomposition assisting in the extrication of ammonia, the liberation of nitrogen, and the consequent germination of the seed, and growth of the plant. Next after turnips, barley, with grass seeds, is sown; and the land having been little exhausted by the previous crop of turnips, affords the soluble parts of the decomposing tops and manure to the barley. The barley is gathered; the grasses, rye-grass and clover, remain, which derive a small part only of their organized matter from the soil, and probably consume the *gypsum* which would be useless to previous and succeeding crops. These grasses, by their large system of leaves, absorb mainly their nutriment from the atmosphere; and, when PLOUGHED IN *at the end of two years*, their decomposed roots and leaves are useful to the *wheat crop*, which is next, and last in succession. At this period of the course, the woody fibre of the farm-yard manure, containing phosphate of lime, is sufficiently decomposed; and as soon as the *most exhausting* crop is taken off the land, recent animal manure is again applied. Pease and beans, in all instances, seem well adapted to prepare the ground for wheat; and in some parts of the country they are raised, alternately with wheat, for years together. Mr. Gregg,—whose ingenious system of cultivation has been published by the Board of Agriculture, and who adopts, upon strong clays, a plan similar to that of the Earl of Leicester, (better known as Mr. Coke of Holkham,)—suffers the ground, after barley, to remain at rest for two years in grass; sows pease and beans on the leys; ploughs in the pea or bean stubble for wheat; and, in some instances, follows his wheat crops by a course of winter tares and winter barley, which is eaten off in the spring before the land is sown for turnips.

It is a great advantage, in the *convertible* system of cultivation, that the whole of the manure is employed as well as the entire resources of the land, in their proper order; those materials which are not fitted for one crop, remaining as nutriment, or essential requisites for the next, or for another.

CHAPTER VIII.

Of the Nature and correct Use of the Excrements of Animals considered as *Manure;* the Mode of its Action and Preservation.—Bone Dust, and dead Animal Matter.

Calico printers for a long time have used the solid excrements of the cow in order to brighten and fasten colours on cotton cloth. This material appeared quite necessary, and its action was ascribed to some latent principle or material derivable from the living animal. But since the action of cow-dung was known to depend on the *phosphates* contained in it, it has been completely replaced by a more cleanly mixture of certain salts, of which the most prominent is *phosphate of soda.*

So, similarly, in medicine, for many centuries the mode of action, or the active principle of all remedies, was veiled in obscurity. But now these principles have been presented to the world in an extremely active and concentrated form. The extraordinary efficacy of Peruvian bark in the cure of fever, is found to depend on the admixture of a minute quantity of a crystalline substance termed *quinine,* with the useless woody fibre; and the causes of the various effects of opium, in as many equally minute yet powerful ingredients in that drug. The inhabitants of Savoy are much infested with the disease known among us as "Derbyshire neck." They have springs which are famous for its cure; we derive benefit from the use of burnt sponge. Now, burnt sponge contains iodine; and upon examination these springs contain iodine in small quantities. The action of the sponge, or of the water, must depend upon some *definite cause* common to both; by ascertaining which we place the action and result completely at our command.

Apply this reasoning to agricultural operations. One practical farmer applies, indiscriminately, any fertilizing material to his land in any state; another, more partial to what is technically termed "short muck," allows violent fermentation to reduce his mixture of straw and dung to one half its weight,—during which operation much gaseous ammonia is disengaged and lost, which, if retained, or supplied to the soil, would have proved extremely serviceable. Both methods cannot be right in all cases.

Besides the dissipation of gaseous matter when fermentation is pushed to the extreme, there is another disadvantage in the loss of *heat*, which, if excited in the soil instead of the dunghill, is useful in promoting the springing of the seed, and in assisting the plant in the first stage of its growth, when it is most feeble and most liable to disease: and the decomposition of manure in the soil must be particularly favourable to the wheat crop, in preserving a genial temperature beneath the surface late in autumn and during winter. These views are in accordance with a well-known principle in chemistry,—that, in all cases of decomposition, substances combine much more readily at the moment of their disengagement than after they have been some time perfectly formed and set at liberty. And in fermentation beneath the soil, the fluid matter produced is applied instantly, even whilst it is warm, to the young organs of the rising plant; and, consequently, is more likely to be efficient, than in manure that has gone through the process, and of which all the principles have entered into new combinations.

It is certainly a matter of indifference whether we employ excrements, ashes, or bones, in carrying out the principle of restoring to the soil those substances which have been taken from it by the previous crop. But, unless we know accurately what *are* those matters that have been actually removed, how is it possible to supply, otherwise than at random guess, the deficiency? Fermented dung may be really useful, if *no nitrogen* be demanded. A time will come when fields will be manured with saline solutions, with the ashes of burnt straw, or with salts of phosphoric acid prepared in chemical manufactories, with as much certainty as now, in medicine, iodine cures the Derbyshire neck, or as quinine is substituted for the bulky powdered bark in fever. The same mixed mass of materials may be useful in one state, less so in another and under other circumstances. A knowledge of the actual wants of the land, and of the exact composition of the proposed manure, is obviously necessary to enable the farmer to adapt the one to the other as a requisite and fitting remedy. If our object be the development of the *seeds* of plants, we know they contain nitrogen. Our manure then must be rich in this material. If by fermentation ammonia be formed in the manure, if it become dry, rotten, and nearly devoid of smell, having lost its previous heat; although it may cut better with the spade, we may be sure it has lost its nitrogen, and, consequently, as far as our object is concerned, (the nutriment of the *seed*,) nearly lost its utility. The leaves, which by their action on the air nourish the stem and woody fibre; the roots, from which the leaves are formed; in short, every part of the structure of a plant contains nitrogen in small and varying proportions. But the *seeds* are always *rich* in nitrogen.

The most important object, then, of farming operations, at least as far as corn is concerned, is the *supply of nitrogen to corn plants* in a *state* capable of being taken up by them,

—the production, therefore, of manures containing the *most* of this element. Gypsum and nitrate of soda are as properly termed manures as farm-yard dung, bone-dust, or night soil; but our present inquiry is, what class of substances contain and yield to corn-plants most NITROGEN? Nature, by the ordinary action of the atmosphere, furnishes as much nitrogen to a plant as is necessary to its bare existence. But plants do not exist for themselves alone:—the greater number of animals depend upon the vegetable world for food; and, by a wise adjustment of nature, plants have the remarkable power of converting, to a certain degree, all the nitrogen offered to them into nutriment for animals. We may furnish a PLANT with carbonic acid, and all the materials which it may require for its mere life; we may supply it with vegetable matter in a state of decay in the most abundant quantity; but it will not attain complete development unless nitrogen be afforded to it by the supply of suitable manure: an herb will, indeed, be formed, but its seeds or grain will be imperfect and feeble.

But when, with proper manure, we supply nitrogen in addition to what the plant would derive from natural sources, we enable it to attract from the air the carbon which is necessary for its nutrition—that is, when that in the soil is not sufficient, we afford it a means of fixing the atmospheric carbon.

There are two principal descriptions of manure, the beneficial agency of which is derivable almost exclusively from the large quantity of nitrogen they yield.

These are the solid as well as fluid excrements of man and animals, their dung and urine.

URINE is employed as manure either singly, in its liquid state, or with the fæces which are impregnated with it. It is the urine contained in night-soil which gives it the property of giving off ammonia, a property which the discharges from the bowels possess only in a very slight degree. Liquid manures act chiefly through the saline substances they hold in solution; whild the solid manures, even of animal origin, contain insoluble matters which decay slowly in the soil, and there become useful only after a time. When we examine what substances we add to a soil by supplying it with urine, we find that this liquid contains in solution ammoniacal salts, uric acid, (a substance itself containing much nitrogen,) and salts of phosphoric acid.

Human urine consists in 1000 parts of

Water, ...	932
Urea, and other organic matters containing nitrogen, ...	49
Phosphates of ammonia, soda, lime, and magnesia, ...	6
Sulphates of soda and ammonia, ...	7
Sal-ammoniac and common salt, . . .	6
	1000

In dung reservoirs, well constructed and protected from evaporation, the carbonate of ammonia, which forms in consequence of putrefaction, is retained in solution; and when the putrefied urine is spread over the land, a part of this ammonia will escape with the water which evaporates. On account of the formation of carbonate of ammonia in putrid urine, it becomes alkaline, though naturally acid in its recent state; and when this carbonate of ammonia is lost by being volatilized in the air, (which happens in most cases,) the loss suffered is nearly equal to one half of the urine employed. So that, if we *fix* the ammonia, (by combining it with some acid which forms with it a compound not volatile,) we increase its action twofold. Now the carbonate of ammonia formed by the putrefaction of urine can be *fixed*, or deprived of its volatility, in many ways.

If, for instance, a field be strewed with gypsum, or plaster of Paris, (in chemical language, sulphate of lime,) and then sprinkled with urine, or the drainings of the cowshed, a double exchange or decomposition takes place. Sulphate of lime and carbonate of ammonia become converted into carbonate of lime (that is, chalk) and sulphate of ammonia; and this because sulphuric acid has a greater affinity for ammonia than it has for lime. This sulphate of ammonia will remain in the soil—it will not evaporate.

If a basin containing spirit of salt, or muriatic acid, be left a few weeks in a close stable or privy, so that its surface is in free communication with the ammoniacal vapours that rise from below, crystals of muriate of ammonia, or common sal-ammoniac, will soon be visible, as an incrustation about its edges. The ammonia that escapes in this way is not only entirely lost as far as vegetation is concerned; it works also a slow but not less certain destruction of the mortar and plaster of the building. For when in contact with the lime of the mortar, ammonia is converted into nitric acid, which gradually dissolves the lime. There are few schoolboys who have not picked out crystals of nitrate of potass, or saltpetre, from an old brick-wall; and in this instance the atmosphere has yielded the ammonia.

The offensive carbonate of ammonia in close stables is very injurious to the eyes and lungs of horses, as the army veterinary surgeons are well able to testify. They adopt measures to carry it off by ventilation and cleanliness. If the floors or stables of cow-sheds were strewed with common gypsum, they would lose all their offensive and injurious smell, and none of the ammonia which forms could be lost, but would be retained in a condition serviceable as manure. This composition, swept from the stable floor, nearly constitutes what is sold under the denomination of *urate*. Manufacturers of this material state, that three or four hundred weight of urate form sufficient manure for an acre: a far more promising adventure for a practical farmer will be to go to some expense in saving his own liquid manure, and, after mixing it with burnt gypsum, to lay it abundantly upon his corn-lands. For, in this way, he may use as much gypsum as will absorb the whole of the urine. Now, in the manufacture of *urate*, the proportion of 10 pounds is employed to every 7 gallons,—allowing the mixture, occasionally stirred, to stand some time, *pouring off the liquid*, and with it nearly all its saline contents, except the ammonia. Urate, therefore, can never present all the virtues of the urine—100 pounds of urate containing no greater weight of saline and organic matter than 10 gallons of urine.

From the foregoing analysis it would appear, that 1000 pounds of human urine contain no less than 68 pounds of *dry* fertilizing matter of the richest quality, worth, at the present rate of selling artificial manures in this country, at least twenty shillings per hundred weight. Suppose we say that the liquid and solid excrements of one human being amount on an average to a pound and a-half daily, then in one year they will amount to 547 pounds; which at the rate of three per cent. of contained nitrogen, would yield sixteen pounds of that material for the land, a quantity sufficient to supply enough for eight hundred pounds of wheat, rye, or oats, or for nine hundred pounds of barley. As each person in reality voids at least one thousand pounds or pints of urine in a year, the national waste incurred in this form amounts, at the above valuation, to twelve shillings a-head upon every individual of the whole population of England and Wales. And if *five tons* of farm-yard manure per acre, added yearly, will keep a farm in good order, *four hundred weight* of the *solid* matter of urine would probably have an equal effect—in other words, the *excrements* of a *a single individual*, are more than sufficient to yield the requisite nitrogen to an *acre* of land, in order to enable it (with the assistance of the nitrogen absorbed naturally from the atmosphere) to produce the richest possible yearly crop. Every town and farm might thus supply itself with the manure, which, besides containing the most nitrogen, contains also the most phosphates; and if an alternation of the crops were adopted, they would be most abundant. By using at the same time bones and wood ashes, the excrements of animals might be completely dispensed with. So that artificial, mineral, or chemical manures are no imperfect substitutes, if applied judiciously.

The urine alone discharged into rivers or sewers by a town population of 10,000 inhabitants would supply manure to a farm of 1500 acres, yielding a return of 4,500 quarters of corn, or an equivolent produce of other crops. The powerful agency of urine as a manure is well known on the Continent, and the Chinese justly consider it as invaluable; and they are the oldest as well as the best agriculturists in the world. Indeed so much value is attached to human excrements by the Chinese, that the laws of the country forbid that any of them should be thrown away; and reservoirs are placed in every house, where they are collected with the utmost care. *No other kind of manure is used for their corn-fields.*

Human urine contains a greater variety of constituents than any other species examined. Urea, uric acid, and another acid similar to it in nature called rosacic acid, acetic acid, albumen, gelatine, a resinous matter, and its various salts, are all valuable to the land, inasmuch as from the land they or their elements have been originally derived. The urine of animals that feed exclusively on flesh contains more animal matter, and consequently more nitrogen, than that of vegetable feeders, whence it is more apt to run into the putrefactive process and disengage ammonia. In proportion as there are more gelatine and albumen in urine, so in proportion does it putrefy more rapidly. Thus, then, all urine contains the essential elements of vegetables in a state of solution; and that will be the best for manure which contains most albumen, gelatine, and urea. Putrid urine abounds in ammoniacal salts, and is only less active as a manure than fresh urine, because of the portion of ammonia which is continually exhaling into the atmosphere.

As to the urine of cattle, it contains less water than that of man, varying with the kind of food on which the animal is fed. A cow will secrete and discharge from two thousand to three thousand gallons of urine a year; and this quantity will contain at least from 1200 to 1500 pounds of *dry solid saline matters*, worth from ten to twelve pounds sterling monies of the realm. Even in the *liquid* state, the urine of one cow, collected and preserved as it is in Flanders, is valued in that country at about £2 a-year. Any practical English farmer may easily make the calculation for himself, how much real wealth is lost in his own farm-yard, how much of the natural means of reproductive industry passes into his drains or evaporates in the air.

The urine of the cow is particularly rich in salts of potash, but contains very little soda. The urine of swine contains a large quantity of the phosphates of ammonia and magnesia. That of the horse contains less nitrogen and phosphates than that of man.

The fertilizing powers of *animal* manures, whether fluid or solid, is dependent, like that of the soil itself, upon the happy admixture of a great number, if not of all, those substances which are required by plants in the universal cultivation they receive from the industry and skill of man, more especially upon the large proportion of *nitrogen* they contain. The amount of this latter material affords the readiest test by which their agricultural value, compared with other matters and with that of each other, can be tolerably well estimated.

Ordinary farm-yard manure, in its recent state, contains a given proportion of nitrogen; but fifteen pounds of blood would yield as much nitrogen as one hundred pounds of farm-yard compost. If dried blood were taken, four pounds would be sufficient; three pounds of feathers, three of horn shavings, five of pigeon's dung, or even two and a half of woollen rags, would counterpoise one hundred of the first named material. Sixteen would be the equivalent number for the urine of the horse, ninety-one that of the cow, seventy-three for horse-dung, one hundred and twenty-five for cow-dung; while the mixed excrements of either animals would correspond with the fact that the discharges of the cow offer no resemblance to those of the horse.

Besides their general *relative* value, namely, as to the proportions of nitrogen they contain, the above matters have a further *special* value, dependent upon the diversity of saline and other organic matters which they severally contain. Thus, three of dried flesh are equal to five of pigeons' dung, as far as nitrogen is concerned; but then pigeons' dung contains a quantity of bone, earth, and saline matter, scarcely present in the former. Hence, the dung of fowls will benefit vegetation in some instances where even horse-flesh, ordinarily regarded as a strong manure, would fail. And why? Evidently because, if saline matters are deficient in the soil, an excessive supply of nitrogen will not serve as their substitute. So the liquid excretions contain much important *saline* matter not present in solid dung, nor in such substances as horn, hair, or wool; and therefore each must be capable of exercising its own peculiar influence, and be *comparatively* useless if deficient of those matters which are also found wanting, deficient, yet necessary in the soil. This affords the reason why no *one* manure can long answer on the same land; it can only supply the materials it contains. When all the silicate of potash in corn-fields is exhausted, urine will not, cannot, supply the deficiency, because it contains no silicate of potash. So long as the land remained rich in this material, urine or blood would supply the requisite nitrogen. Hence, in all ages and countries, the habit of employing *mixed* manures and artificial composts has been universally diffused. What is wanting is a more accurate knowledge of the precise deficiency at any given moment, and a consequent saving of capital from unnecessary waste, together with an immense increase in fertility, as the reward of so accurate an adaptation of means and ends. The knowledge of a disease is essential to the correct application of a remedy.

A high degree of culture requires an increased supply of manure. With its abundance, the produce in corn and cattle will augment, but must diminish with its deficiency.

From the foregoing remarks, it must be evident, that the greatest value should be attached to the *liquid* excrements of man and animals when a manure is desired which shall supply *nitrogen* to the soil. And as nitrogen is seldom wanted alone,—and as, generally, in practice, both liquid and solid excrements are found associated, containing, besides nitrogen, many other essential and invaluable ingredients,—too much care cannot be taken, not only in preserving them, but, which is equally important, in securing to the land the full value of their operation, by applying them, in the best possible condition, for the development of their powers.

We have already alluded to the loss sustained by the fermentation of dung-heaps. As we observed, in an earlier section, when it is considered that, with *every pound of ammonia* which evaporates, a loss of *sixty pounds* of corn is sustained, and that, with every pound of urine, a pound of wheat might be produced, the indifference with which liquid refuse is allowed to run to waste is quite incomprehensible. That it should be allowed to expend its ammonia by fermentation in the dung-heap, and evaporation into the atmosphere, is ascribable solely to *ignorance* of the elementary outlines of that science which hitherto the practical farmer has thought it no disgrace, but rather an honour to publish, glorying in his utter disregard of all bookish knowledge, and substituting his own notions of wasteful and vague experience, for the calm deductions of sound and rational investigation. In most places, only the solid excrements impregnated with the liquid are used; and the dunghills containing them are protected neither from evaporation, nor from rain. The solid excrements contain the insoluble, the liquid excrements all the soluble phosphates; and the latter contain, likewise, all the potash which existed as organic salts in the plants consumed by the animals which feed upon them.

It is by no means difficult to prevent the destructive fermentation and heating of farm-yard compost. The surface should be defended from the oxygen of the atmosphere. A compact marl, or a tenacious clay, offers the best protection against the air; and before the dung is covered over, or, as it were, sealed up, it should be dried as much as possible. If the dung be found at any time to heat strongly, it should be turned over, and cooled by exposure to air. Watering dung-hills is sometimes recommended for checking the process of putrefaction, and the consequent escape of ammonia; but this practice is not consistent with correct chemistry. It may cool the dung for a short time; but moisture is a principal agent in all processes of decomposition. Water, or moisture, is as necessary to the change as air; and to supply it to reeking dung, is to supply an agent which will hasten its decay.

If a thermometer, plunged into the dung, does not rise much above blood-heat, there is little danger of the escape of ammonia. When a piece of paper, moistened with spirit of salt, or muriatic acid, held over the steams arising from a dung-hill, gives dense fumes, it is a certain test that decomposition is going too far; for this indicates that ammonia is not only formed, but is escaping to unite with the acid in the shape of sal-ammoniac.

When dung is to be preserved for any time, the situation in which it is kept is of importance. It should, if possible, be defended from the sun. To preserve it under sheds would be of great use, or to make the site of a dung-hill on the north side of a wall. The floor on which the dung is heaped, should, if possible, be paved with flat stones; and there should be a little inclination from each side towards the centre, in which there should be drains, connected with a small well, furnished with a pump, by which any fluid matter may be collected for the use of the land. It too often happens, that a heavy, thick, extractive fluid is suffered to drain away from the dung-hill, so as to be entirely lost to the farm.

Night-soil, it is well known, is a very powerful manure, and very liable to decompose. Human excrements differ in their composition, but always abound in nitrogen, hydrogen, carbon, and oxygen. From the analysis of Berzelius, it appears that a part of it is always soluble in water; and in whatever state it is used, whether recent or decomposed, it supplies abundant food to plants. But this affords no excuse for its misapplication in any other condition than that which is most profitable. It varies, no doubt, in richness with the food of the inhabitants of each district,—chiefly with the quantity of *animal* food they consume,—but, when dry, no other SOLID manure, weight for weight, can probably be compared with it in general efficacy. The soluble and saline matters it contains are made up from the constituents of the food we eat; of course, it contains most of those elementary substances which are necessary to the growth of the plants on which we live. The disagreeable smell of night-soil may be destroyed by quick lime. If exposed to the air in thin layers strewed over with lime, in fine weather, it speedily dries, is easily pulverized, and, in this state, may be used in the same manner as rape-cake, and delivered into the furrow with the seed. If night-soil be treated in a proper manner, so as to remove the moisture it contains, without permitting the escape of its ammonia, it may be put into such a form as will allow it to be transported even to great distances. This is already attempted in many places; and the preparation of human excrements for exportation constitutes not an unimportant branch of industry. But the manner in which this is done, is not always the most judicious. In Paris, the excrements are preserved in the houses in open casks, from which they are collected and placed in deep pits at Montfauçon; but they are not sold till they have attained a certain degree of dryness by evaporation in the air. But whilst lying in the receptacles appropriated for them in the houses, the greatest part of their urea is converted into carbonate of ammonia; lactate and phosphate of ammonia are also formed, and the vegetable matters contained in them putrefy; all their sulphates are decomposed, whilst their sulphur forms sulphuretted hydrogen. The mass, when dried by exposure to the air, has lost more than half of the nitrogen which the excrements originally contained; for the ammonia escapes into the atmosphere along with the water which evaporates; and the residue now consists principally of phosphate and lactate of ammonia, and small quantities of urate of magnesia and fatty matter. Nevertheless, it is still a very powerful manure; but its value as such would be twice or four times as great, if the excrements, before being dried, were neutralized with a cheap mineral acid.

In other manufactories of manure, the excrements, whilst still soft, are mixed with the ashes of wood, or with earth; both of which substances contain a large quantity of caustic lime, by means of which a complete expulsion of all their ammonia is effected, and they are completely deprived of smell. But such a residue applied as manure, can act only by the phosphates which it still contains; for all the ammoniacal salts have been decomposed, and their ammonia expelled. In London, night-soil is dried with various mixtures; while, in other of our large towns, what is called "animalized charcoal" is prepared by mixing and drying night-soil with gypsum and ordinary wood charcoal in fine powder. In all cases, the excrements of human beings contain *more* nitrogen than those of any other animal. Berzelius obtained, by the burning of 100 parts of dried excrements, 15 parts of ashes, principally composed of the phosphates of lime and magnesia.

It is quite certain that the *vegetable* constituents of the excrements with which we manure our fields, cannot be entirely without influence upon the growth of the crops on them; for they will decay, and thus furnish *carbonic acid* to the young plants. But it cannot be imagined that their influence is very great, when it is considered that a good soil is manured only once every six or seven years; that the quantity of carbon thus given to the land corresponds only to 5 per cent. of what is removed in the form of herbs, straw, or grain; and further, that the rain-water received by a soil contains much more carbon in the form of carbonic acid than these vegetable constituents of animal excrement.

The *peculiar* action, then, of SOLID, as opposed to fluid, animal excrements, is limited to their *inorganic* constituents, rather than to the presence of the partially changed vegetable or organized matter which they contain. Horse dung contains a large proportion of such partially altered vegetable matter; and the reason why night-soil is a more powerful manure, is that, relatively, it contains less vegetable matter, while nitrogen is more abundant; and this, principally, because its weight is materially made up by the liquid excrement, or urine, always forming part of its composition. Now, urine easily putrefies, and yields ammonia largely; and this because of its containing more animal matter than is contained in dung. A horse lives exclusively on vegetables; and 100 pounds of the urine of a healthy man, (living, of course, partially upon flesh, and partly upon those seeds and parts of plants containing nitrogen, in quantity,) will yield as much nitrogen as 1300 pounds of fresh horse-dung, or 600 of cow-dung. We cannot ascribe much of the power of the excrements of cattle, sheep, and horses, to the *nitrogen* which *they* contain, for the quantity derivable from these vegetable feeders is too minute. The restoration of *inorganic* matter to the land, is the *chief* value arising from the application of the dung of cattle. A certain amount of inorganic matter is removed with every crop. If we manure that land with the dung of the cow or sheep, we restore to the surface silicate of potash, and some salts of phosphoric acid. If we use horse-dung, we supply, chiefly, phosphate of magnesia and silcate of potash. In the straw which has served as litter, we add a further quantity of silicate of potash, and phosphates, which, if the straw be already putrefied, are exactly in the same state as before they formed part of the crop which yielded them.

But, if we use human excrements, in addition to the phosphates of lime and magnesia, we supply a larger proportion of compounds of nitrogen, essential to the development of those parts of plants upon which human beings are accustomed to feed: and, by a wise ordination, corn-plants are found associated with human dwellings,—in other words, the family of man having selected such spots on the earth's surface, as are fitted for the growth of corn, animal manure is always at hand in quantity for its artificial cultivation; thus restoring, through the feculent discharges of man and animals resident on the spot, precisely those materials which the process of growth has removed from the soil.

Cow-dung is not incorrectly said to be "cold:" so much of the saline, nutritive, and other organic matters from the cow, pass off almost exclusively with her urine, that her dung does not readily heat and run into putrefaction. Still, mixed with other manures, or well diffused through the soil, its vegetable matter is not useless. It loses more than any other similar substance in drying. The dung of pigs is soft and *cold*, like that of the cow; containing, like it, nearly 80 per cent of water. Mixed with other manures, it may be applied to any crop; but is of very variable quality, owing to the variety of food of the animal.

The horse is fed, generally, on less liquid food, less succulent and watery than that of oxen. He discharges less urine,—hence his dung is richer in animalized matter: or, adopting the figurative language of the farmer, it is *hotter*, and, indeed, runs more readily into the putrefactive fermentation.

If the *solid* excrements of animals are chiefly valuable for the saline, earthy, and inorganic constituents they restore to the soil which has yielded them, it will be readily inferred, that instead of dung or night-soil, other substances, containing their peculiar ingredients, may be substituted. One hundred tons of fresh horse-dung, if dried, would leave only from 25 to 30 tons of solid matter, the rest being only water; and if this dried matter (itself only one-fourth of the original weight) were burnt, so as to decompose its vegetable ingredients, we should obtain, perhaps, 10 per cent. of really useful saline and earthy matters, (one-fortieth of the original weight,) according to the richness or poverty of the food the horse had taken.

Now, this *minute* proportion of saline and earthy matters, and its *relative quantity*, in the various kinds of dung or excrement, forms, evidently, the chief topic of interest to which our attention should be directed; inasmuch as what is left upon such examination and analysis, is exactly what has made up the component inorganic parts of the hay, straw, grass, or oats, on which the animal has been fed; or, in other words, exactly what has been removed from the soil, and requires to be replaced, if the next crop is to equal the last. If our object is increased fertility, more must be added than has been taken away. Hay, straw, and oats, formed (for illustration' sake) the food of a horse. Their principal constituents are the phosphates of lime and magnesia, carbonate of lime, and silicate of potash; the first three of these preponderated in the corn, the latter in the hay, and these, removed from the soil with the crop, are precisely the saline matters which would be found in the excrement of the animal for whose support that crop was intended.

In order, then, to atone for the absence of that excrement which derives its value from the soil which has produced it, and for which it is peculiarly fitted, as containing what that soil has lost, the *ashes of wood* or *bones* may often be judiciously substituted; and for this reason; wood-ashes contain silicate of potash, exactly in the same proportion as that salt is found to exist in the *straw* of the last crop; and as to *bones*, the greatest part of their bulk consists of the phosphates of lime and magnesia. Ashes obtained from various trees are of unequal value: those from oak-wood are the least, those from beech most serviceable. With every 100 pounds of the ashes of the beech spread over a soil, we furnish as much *phosphates* as 460 pounds of fresh night-soil could yield. But night-soil contains other useful matters besides phosphates; hence the utility of mixed composts, as, evidently, the ashes of the beech would not alone secure fertility.

Bone manure possesses still greater importance than wood ashes as a substitute for an indefinite and large supply of animal excrement. The primary sources from which the bones of animals are derived are,—the hay, straw, or other substances which they take as food. Now, bones contain more than half their weight of the phosphates of lime and magnesia; and hay contains as much of these salts as wheat straw. It follows, then, that 8 pounds of bones contain as much phosphate of lime as 1000 pounds of hay or wheat straw; and 2 pounds of bones as much as is found in 1000 of the grain of wheat or oats. These numbers express pretty exactly the quantity of *phosphates* which a soil yields annually on the growth of hay and corn. Upon every acre of land appropriated to the growth of wheat, clover, potatoes, or turnips, forty pounds of bone-dust will be found sufficient to furnish an adequate supply of *phosphates* for three successive crops.

To secure the best application of bones, they should be reduced to powder; and the more intimately they are mixed with the soil, the more easily are they taken up and assimilated. The most easy and practical mode of effecting this, is to pour over the bones, in powder, half their weight of sulphuric acid, (or oil of vitriol,) diluted with three or four parts of water; and after they have remained in contact for some time, say a fortnight, to add one hundred parts of water, and sprinkle this mixture over the field before the plough. Bones may be preserved unchanged, for thousands of years, in dry, or even in moist soils, provided the access of rain be prevented, as is exemplified by the bones of animals, buried previous to the flood, found in loam or gypsum; the interior parts being protected by the exterior from the action of water. But they become warm when reduced to a fine powder; and moistened bones generate heat, and enter into putrefaction;—the gelatine which they contain is decomposed, and its nitrogen converted into carbonate of ammonia, and other ammoniacal salts, which are retained, in a great measure, by the powder itself. Bones burnt till quite white, and recently heated to redness, will absorb seven times their volume of ammoniacal gas. The analysis of bone enables us to say, that while 100 pounds of bone-dust add to the soil 33 of gelatine, the *organized* substance of horn, or as much organized matter as is contained in 300 or 400 pounds of blood or flesh, they add, at the same time, more than half their weight of *inorganic* matter, lime, magnesia, soda, common salt, and phosphoric acid, in combination with some of these;—all of which, as we have seen, must be present in a fertile soil, since the plants require a certain supply of them all at every period of their growth, but more especially during the maturation of the straw and grain. These substances, like the inorganic matter of plants ploughed into the soil, may, and do exert a beneficial agency upon vegetation after all the organized structure of such decaying plants is broken up and destroyed. One hundred parts of *dry* bones contain 33 per cent. of dry gelatine, and are equivalent to 250 parts of recent human urine. We do not speak now of the bone-dust which remains after all the animal gelatine is removed, in boiling them to extract size for the calico-printer.

HORN is a still more powerful manure than bone,—that is to say, it contains a greater proportion of organized animal matter. The peculiarity is, that horn, hair, and wool, as organized substances, are *dry;* while blood and flesh contain from 80 to 90 per cent. their weight of water. Hence, a ton of horn-shavings, of hair, or of dry woollen rags, ought to enrich the soil with as much animal matter, (and consequently nitrogen,) as would be yielded by ten tons of blood. In consequence of this dryness, horn and wool decompose more slowly than blood; and hence, the effect of soft animal matters is more immediate and apparent than that of hard and dry animal matters, the action of which is, nevertheless, stronger, and continues for a longer period.

The refuse of the different manufactories of skin and leather form very useful animal manures; such as the shavings of the currier, furrier's clippings, and the offals of the tan-yard and of the glue-maker. The gelatine contained in every kind of skin is in a state fitted for its gradual decomposition; and when buried in the soil, it lasts for a considerable time, and constantly affords a supply of nutritive matter to the plants in its neighbourhood. These manures contain nitrogen as well as phosphates, and, consequently, are well fitted to aid the process of vegetable growth.

From what has been stated, we may arrive at the following conclusions:—

1. That fresh human urine yields nitrogen in greater abundance to vegetation than any other material of easy acquisition; and that the urine of animals is valuable for the same purpose, but not equally so.

2. That the mixed excrements of man and animals yield, (if carefully preserved from further decomposition,) not only nitrogen, but other invaluable saline and earthy matters that have been already extracted in food from the soil.

3. That animal substances which, like urine, flesh, and blood, decompose rapidly, are fitted to operate *immediately* and powerfully on vegetation.

4. That *dry* animal substances, as horn, hair, or woollen rags, decompose slowly, and (weight for weight) contain a greater quantity of organized as well as unorganized materials, manifesting their influence it may be for several seasons.

5. That bones, acting like horn, in so far as their animal matter is concerned, and like it for a number of seasons more or less, according as they have been more or less finely crushed, may ameliorate the soil by their earthy matter for a long period, (even if the jelly they contain have been injuriously removed by the size maker,) permanently improving the condition and adding to the natural capabilities of the land.

CHAPTER IX.

Of the comparative Value of Vegetable Manure, as contrasted with Animal Excrements.

It may be asked, if the principal sources of the nitrogen required for the artificial forcing of corn-plants be the feculent excretions of man and animals,—if the object be chiefly to replace in the soil those matters which have been abstracted with the previous crop,—how is it that such excrements more effectually restore those elements, than would occur if the ripe crop were ploughed into the soil; in other words, how is it that dung and urine are richer in nitrogen than the food from which they are formed?

The answer is easy and obvious. The BULK of a vegetable is chiefly woody fibre or carbon. A horse lives exclusively upon vegetables, and discharges from his lungs, in breathing, a large portion of the carbon his food contains; hence, what is left to be thrown off from his kidneys and bowels, contains *relatively* a greater proportion of nitrogen which could only be otherwise feebly supplied to the soil from the rain-water of the atmosphere, while the air yields to the land carbon in abundance. Nearly the whole of the nitrogen contained in his food, (indeed, all beyond what is necessary for the wants of his own living system,) is thrown off in his urine and dung. In the food consumed, the carbon was to the nitrogen as 9 to 1: in that which remains, after breathing has done its work, the carbon is to the nitrogen in the proportion of only 2 to 1. It is out of this residue, *rich in nitrogen*, that the several parts of animal bodies are built up. Warm-blooded animals with capacious lungs, double and triple their weight very rapidly after birth: they take in (as lambs or calves after separation from the parent) only vegetable food; but the rapidity of its decomposition is the index or ratio of the rapidity of their growth. Their actions are lively; and the playful exertion of their muscles renders the decomposing play of the heart, and consequently of the lungs, more frequent than when fully grown. During their quick growth, they *absorb* all the nitrogen their food contains, while they throw off carbon from the lungs. After growth is finished, they still throw off, in breathing, nearly all the carbon, while the residual quantity of nitrogen (not wanted for the purposes of the living system) escapes in the dung and urine. The urine of a child would not, upon putrefaction, disengage the same quantity of ammonia as that of a full-grown man. Hence the reason why bodies can be nourished and built up upon food comparatively poor in nitrogen; and yet not only do those same bodies contain nitrogen in quantity, but also their excretions are rich in the same element. The more nitrogen that is appropriated by growing cattle, the less will pass off into the fold-yard; hence it is natural to expect that the manure, either liquid or solid, which accumulates where many young animals are fed, will not be so *rich* as that yielded by full-grown cattle, unless, by giving richer food to the young cattle than they actually require or can dispose of, the difference to the dung-heap be made up. A little acquaintance, then, with first principles will explain the seeming difficulty, how it is that the dung or urine of animals has a greater fertilizing power than even the whole weight of the food which they have consumed would have, if laid upon the soil. Its carbon has passed through the lungs of animals that have eaten it into the atmosphere: and the soil can always supply itself with sufficient carbon from the decomposition of the carbonic acid of the air; while its *natural* supply of nitrogen for the plants which grow on its surface is *limited* to the decomposition of the ammonia, and the evolution of nitrogen from rain-water,—a quantity which, though sufficient for the sustenance of crabs, will not serve for apples; and we must remember, that corn-plants are not in a state of nature,—wild oats or potatoes are widely different from the same plants under the care and culture of man. The difference between a wild and a cultivated vegetable is not merely an increment of *size*, but the development of those parts which, though *naturally* containing nitrogen, contain, *proportionally*, far less than by artificial culture they may be compelled to take up.

The doctrine of the proper application of manures from organized substances offers an illustration of an important part of the economy of nature, and of the happy order in which it is arranged. The death and decay of animal substances tend to resolve organized forms into elementary constituents; and the pernicious effluvia disengaged in the process seem to point out the propriety of burying them in the soil, where they are fitted to become the food of vegetables. The fermentation and putrefaction of organized substances in the free atmosphere are noxious processes: beneath the surface of the ground, they are salutary operations. In this case, the food of plants is prepared where it can be used, and that which would offend the senses and injure the health, if exposed, is converted, by gradual processes, into forms of beauty and of usefulness: the stinking gas is rendered a constituent of the perfume of a flower; and what might be poison, swells the food of animals and man.

CHAPTER X.

Of Manures of Mineral Origin, or Fossil and Artificial or Chemical Manures; their Preparation, and the Manner in which they Act.—Of Lime in its Different States; its Operation as a Manure.—Of Alkalies, and Common Salt, as to their Action upon the Land.

From what has been already said, a great variety of substances contribute to the growth of plants, and supply the materials of their nourishment. How matters that have once been living are in turn converted into the substance of other living things, may be comprehended; but it is more difficult to understand those operations by which earthy and saline matters are taken up and consolidated in the fibre of vegetables.

Sir Humphrey Davy, quoting the experiments of continental chemists who had preceded him, states, on their authority, that different seeds sown in fine sand—flour of brimstone, or rust of iron, and supplied only with air and water, produced healthy plants, which by analysis yielded various earthy and saline matters, which either were not contained in the seeds or the material in which they grew; and hence they and he concluded, that they must have been formed from air or water, in consequence of the agencies of the living organs of the plant.

It would be impossible to pass this interesting fact, without observing how strikingly it confirms the views advanced in the preceding pages as to the origin of nitrogen from the ammonia in rain-water. Sir Humphrey contends, from some subsequent experiments, that the atmosphere yields no saline matter to plants; but the existence of ammonia in rain-water, if not unknown to that distinguished chemist, was overlooked in his computation.

The only substances that can, with propriety, be called *fossil manures*, and which are found unmixed with the remains of any organized beings, are certain alkaline earths, or alkalies, and their combinations.

The only alkaline earths which have been hitherto applied in this way, are LIME and *magnesia*. Potash and soda, the two fixed alkalies, are both used in certain of their chemical compounds, but never in a pure or caustic state.

The most common form in which LIME is found on the surface of the earth, is in a state of combination with carbonic acid. We have already alluded to some of its chemical properties in a previous section of this work. When common limestone is burnt in the kiln, the carbonic gas is driven off by the heat, and nothing remains but the pure caustic earth. If the fire have been very high, it approaches to one-half the weight of the stone; but, in common cases, limestones, if well dried before burning, do not lose much more than from 35 to 40 per cent., or from 7 parts to 8 out of 20.

Very few limestones, or chalks, consist entirely of lime and carbonic acid. Statuary marble is nearly a pure carbonate of lime. When a limestone does not copiously effervesce in acids, and is yet sufficiently hard to scratch glass, it contains the earth of flint, and, probably, the earth of clay. When brownish or yellowish-red, the tinge, in all probability, depends upon the presence of iron. If not hard enough to scratch glass, if the stone effervesce slowly or but slightly with acids, and the solution have a *milky* appearance,—most probably *magnesia* is present.

Before any opinion can be formed of the manner in which the different ingredients in limestones modify their properties, and their consequent action upon the soil, it will be necessary to consider the action of pure, or recently burnt caustic lime, when employed for agricultural purposes.

Quicklime,—in its pure state, whether in powder, or dissolved in minute proportion, in water,—is *directly injurious to plants.* Grass may be certainly killed by sprinkling it with lime-water; but since lime is a necessary ingredient in soils, and an useful addition in many cases, it evidently must be that its combination with carbonic acid—the state in which it is found naturally—is the circumstance which not merely renders it void of causticity, but so far alters its properties, as to exchange injury for advantage. Lime, if pure, and recently burnt, cannot long remain caustic, inasmuch as it rapidly attracts sufficient carbonic acid from the atmosphere to reduce it to the state of chalk, or a carbonate; and it is a wise arrangement that it is so,—that it is never found, in nature, pure or free from this acid.

Nevertheless, there are cases in which the application of caustic lime may be requisite. If it be mixed with any moist, fibrous, vegetable matter, there is a strong action between the lime and the vegetable fibrin: they form a kind of compost together, of which a part is usually soluble in water. By this kind of operation, lime renders matter which was comparatively inert, nutritive, or, at least, soluble; and as charcoal and oxygen abound in all plants, the lime becomes at the same time usefully converted, even by their agency, into a carbonate. It is obvious, then, that the operation of quicklime, and that of marl or chalk, depends upon principles altogether different. Quicklime, in being applied to land, tends to bring any hard vegetable matter that it contains into a more rapid and easy state of decomposition; while chalky forms of lime only add the necessary amount of this earth, so as to furnish the requisite supply to be absorbed as part of the inorganic structure of the plants which grow in that spot. Quicklime, when it becomes mild by exposure, acts in the same way as chalk, but, in the act of becoming mild, it prepares soluble out of insoluble matter.

It is upon this circumstance that the operation of lime in the preparation for wheat crops depends, and its efficacy in fertilizing peats, and in bringing into a state of cultivation all soils abounding in hard roots, dry fibres, or undecomposed and, therefore, useless vegetable matter.

So, then, the solution of the question, Whether quicklime ought to be applied to a soil? depends upon the quantity of the undecomposed vegetable matter that soil contains; and the answer to the question, Whether marl, or any chalky carbonate of lime, ought to be applied? evidently depends upon whether the previous crops have exhausted the requisite quantity of lime necessary to form part of the inorganic material of the crop that is intended to be raised there. All soils are improved by mild lime, because each successive crop takes a portion of lime away. But, perhaps, one of the most important and influential agencies of lime in soil to which it is added, is to be found in its ready combination with *nitric acid*, which it assists in forming, from the facility with which it promotes the union of its already existing elements, *nitrogen* and *oxygen*. NITRATE OF LIME, which, by a series of inevitable actions, is produced in the decomposing soil, is very soluble in water: entering readily into the roots of plants, it forms the medium by which lime becomes part of a vegetable, (for, as before stated, the earths and alkalies never enter a plant in a pure, free, caustic, or uncombined state,) and producing upon growth effects precisely similar to those of the now well-known *nitrate of soda*. Ploughing, harrowing, digging, and turning over the soil to the action of the air, is useful, chiefly, because it facilitates the more ready action of the atmosphere, indispensable to the formation of these *nitrates*.

Besides pure, or caustic lime, and its carbonate, in the form of chalk or marl, the application of *gypsum*, or SULPHATE OF LIME,—sometimes called alabaster, or plaster of Paris,—deserves a passing notice. Great difference of opinion has prevailed among agriculturists as to its use. Correct notions as to the nature of vegetable growth, an exact acquaintance with the constitution of plants intended to be raised upon a given locality, and the admitted necessity for an equally exact acquaintance with the existing condition of that soil, so as to adapt the one to the other,—in fact, a better knowledge of agricultural chemistry,—is all that alone is wanting, or can solve the variety of opinion as to its employment. Plaster of Paris has been advantageously used in England, and various testimonies as to its utility have been laid before the Board of Agriculture. Doubtlessly, if lime be deficient in a soil, though marl, or the carbonate, is more easily susceptible of action, the sulphate or gypsum, which is less so, less easily decomposed, is better than none. Sulphuric acid has a stronger affinity for lime than carbonic acid can exert; hence, gypsum does not so readily enter into new combinations. It has been said, that sulphate of lime assists the putrefactive decomposition of animal substances,—that it hastens the evolution of ammonia, and the consequent development of nitrogen; but the experiments of Sir Humphrey Davy disprove this view of the case. It would appear that peat-ashes naturally contain gypsum in abundance. These peat-ashes are used with advantage in some parts of the country, as a top-dressing for cultivated grasses, particularly clover; and, in examining the ashes of sainfoin and clover, they have been found to contain gypsum in quantity, proving that lime, in the form of a sulphate, is a necessary ingredient in the constitution of some vegetables. The practical deduction from such investigations obviously is, that if clover be intended to be raised upon a soil deficient of lime, in the form of a sulphate, gypsum will not only constitute an advantageous manure, but one that is absolutely essential to the production of a vigorous, abundant, and healthy crop.

Phosphate of lime is another combination of this earth with an acid. It forms the greatest part of calcined bones, of the utility and application of which we have already spoken. It exists in most excrementitious substances, and is an essential constituent of the straw and grain of wheat, barley, oats, and rye, and likewise in beans, peas, and vetches. It exists in some places, in these islands, native, but only in small quantities. Phosphate of lime is generally conveyed to the land in the composition of other manure, and is absolutely necessary to corn crops. Bone-ashes, ground to powder, are useful on arable land that is deficient in lime, or its phosphate, especially if there be a superabundance of vegetable matter. If lime, or its phosphate, be the only deficient ingredient in the land,—if it already contain, or be at the same time supplied with animal manure, yielding nitrogen,—then bone-dust may prove useful.

WOOD-ASHES consist principally of the vegetable alkali, or potash, united to carbonic acid; and as this alkali is found in almost all plants, it is not difficult to conceive that it may form an essential part of their organs. The general tendency of the alkalies applied as manure is, to supply the deficiency occasioned by what is removed with the previous crops. Wood-ash contains not only carbonate of potash, but also the sulphate of potash and *silicate* of potash; hence its utility, as affording silex to wheat straw,—a material essential to its firmness and stability. These saline matters in wood-ash are all valuable, as supplying the necessary inorganic constituents of plants; and hence the extensive use of wood-ash, as a manure, in every country where it can readily be procured.

PEAT-ASHES vary, in constitution, with the kind of peat from which they have been prepared. They often contain traces of potash and soda, and generally a quantity of sulphate and carbonate of lime, a trace of phosphate of lime, and much siliceous matter. In almost every country where peat abounds, the value of peat-ashes, as a manure, has been more or less generally recognised.

KELP. The ash left by the burning of sea-weed contains potash, soda, silica, sulphur, and several other of the inorganic constituents of plants, and is usefully and extensively employed in many districts near the sea, where plants naturally requiring these materials grow more luxuriantly than in more inland districts. Sea-weeds decompose with great rapidity when collected in heaps and laid upon the land. During their decay, they not only yield inorganic saline matter to the soil, but enrich it with an additional layer of vegetable mould.

Nitrate of soda, and *nitrate of potash* or *saltpetre.* These substances have been much commended for their beneficial action upon *growing* plants. They impart to the leaves a deeper green, and evidently quicken vegetable action: they are applied advantageously to grass and young corn, at the rate of a hundred weight of either to an acre. The nitric acid they contain yields the additional nitrogen beyond the quantity the plants can obtain by decomposing the ammonia contained in the rain that falls upon them; at the same time, the other ingredient—potash or soda, as the case may be—is put within the reach of their roots, to be absorbed as an inorganic, yet necessary constituent.

Common salt, muriate of soda, or, more correctly, a compound of the metal sodium with elementary chlorine, is undoubtedly indispensable to the fertility of many *inland* soils. It is not without design that the spray of the sea is allowed to be borne by the winds for many miles over the shore, so supplying an ample dressing of common salt to the land. A minute quantity is absolutely necessary to the healthy growth of all our cultivated crops, and most lands (in this island at least) contain a sufficient quantity of it for the purposes of vegetation. Common salt is found in every species of animal manure, and will be found most requisite in high situations exposed to the washing of heavy rains, which tend to remove the soluble alkaline matters from the soil. Much diversity of opinion has prevailed as to the utility of this substance. The Cheshire farmers plead in its favour. On the other hand, that salt in large quantities, renders land barren, was known long before any records of agricultural science existed. We read in Scripture, that Abimelech took the city of Shechem, and sowed he land with salt, that the spot might be forever unfruitful. Pliny, a Latin historian, though he recommends giving salt to cattle, yet affirms, that when strewed over land it renders it barren. But these form no argument against the proper application of it. There can be no question that salt, as well as many other similar mineral substances, are really useful to vegetation; yet the intelligent agriculturist ought not to be surprised to find, that a substance which is useful, because necessary and deficient in one instance, may be positively in excess, and consequently injurious, if added in another. He will try cautiously, and upon a small scale, whether this or that material seems fitted to answer his intention; or, what is far better than blind hit-or-miss experiment, he will endeavour to ascertain the actual constitution of the soil, and not expect to grow wheat where there is no phosphate of lime or silicate of potash; nor plants which thrive best near the sea, in a soil which he knows to be devoid of common salt. If salt be there, it is a needless and foolish waste to attempt to improve the land by adding more. If he has already bricks enough at hand, you must carry the builder mortar: more bricks will not supply the place of mortar. So, if the soil contain lime, or magnesia, or potash, in sufficient abundance for the wants of the plant it is our object artificially to force, it may still be deficient of other materials; and here the skill and science of one man stand in beautiful contrast with the blundering, bungling guesses of another.

At a meeting of the Chemical Society, a paper was lately read, containing a report of some experiments with saline manures containing nitrogen, conducted on the Manor Farm, Havering-atte-Bower, Essex, in the occupation of C. Hall, Esq., communicated by W. M. F. Chatterley, Esq. The experiments were suggested by the prevailing opinion, that the fertilizing power of some animal manures, and of the salts, nitre, (nitrate of potash,) nitrate of soda, and sulphate of ammonia, depend upon the proportion of nitrogen they contain. The salts mentioned are all, from their low price, within the reach of the farmer; and the quantity of the last thrown into the market is greatly increasing, from the extension of the new mode of purifying coal-gas from its ammonia, by washing the gas with diluted sulphuric acid. The interest also of experiments with salts is greater than with mixed manures, both to the farmer, who, from the nature of the former substances, may depend upon their uniformity, and to the chemist, as their composition is necessarily known to him. A field of wheat was chosen, which, in the latter end of April, 1842, presented a thin plant; the salts were top-dressed over the land by hand, on the 12th of May, and the crop mowed on the 10th of August. The soil was rather poor, consisting of a heavy clay upon a subsoil of the London clay. 1. No manure; corn per acre 1413 lbs. 2. With 28 lbs. of sulphate of ammonia; corn, 1612 lbs. 3. With 140 lbs. of the same salt; corn, 1999 lbs. 4. With 112 lbs. of nitrate of soda; corn, 1905 lbs. 5. With 112 lbs. of nitre; corn, 1890 lbs. The increase in the straw was also considerable in all cases, except with the small proportion of sulphate of ammonia. The total increase in the four manured crops was per cent., in the order in which they were enumerated,—14.1, 41.5, 34, and 33.5. The cost of the manure for the three last did not greatly differ, being 21s. 9d., 24s. 6d., 27s. 6d.; and the profit on the outlay was, with the small dose of sulphate of ammonia, 294 per cent.; with the large dose, 212 per cent.; with the nitrate of soda, 138 per cent.; and with the nitrate of potash, 92 per cent. The principal conclusions drawn by the author are, that the increase of nitrogen in the crop is greater than is accounted for by the nitrogen of the manures, showing that these manures have a stimulating effect, or enable the plants to draw additional nitrogenized food from the soil and atmosphere; the considerable superiority of sulphate of ammonia over the other salts, and the greater proportional efficiency of a small, than of a large dose of that salt. The sulphate of ammonia costs 17s. per cwt. It appears best to apply this salt in the proportion of about 1 cwt. per acre, at three different dressings: the first quantity when the crop of wheat makes its spring growth, or if of oats, when about two inches above the ground; the second quantity about a month afterwards; and the third at the time of the formation of the ear. To meet the practical difficulty of distributing so small a quantity as one-third of a hundredweight over an acre, about twice the quantity of common salt or of soot may be mixed with the ammoniacal salt. These, and most saline manures, when used as a top-dressing, should be supplied to the plant when dry, after a shower of rain, or during hazy weather.

That which was true in the day of Sir Humprey Davy, when experimental agricultural chemistry was in its infancy, is equally true at the present moment. He observes that "much of the discordance of the evidence relating to the efficacy of *saline* substances depends upon the circumstance of their having been used in varying proportions, and in general in quantities much too large." That which is salutary and medicinal in moderate doses, not only may be, but is absolutely poisonous in another.

Sir Humphrey made a number of experiments on the effects of different saline substances on barley and on grass growing in the same garden, the soil of which was a light sand, of which 100 parts were composed of 60 parts of siliceous sand, and 24 parts finely-divided matter, consisting of 7 parts carbonate of lime, 12 parts alumina and silica, less than one part saline matter, principally common salt, with a trace of gypsum and magnesia; the remaining 16 parts were vegetable mould. The solutions of the saline substances were used twice a week, in the quantity of two ounces, on spots of grass and corn, sufficiently distant from each other to prevent any interference of results. Several of the salts of potash, soda, magnesia and ammonia were experimentally and separately employed. He found that in all cases, when the quantity of the salt equalled *one-thirtieth* part of the weight of the water, the effects were injurious; but least so with the salts of ammonia. When the quantities of the salts were one part in three hundred of the solution, or 1 pound to 300 pounds of water, the effects were different. Those spots watered with the solution of carbonate of ammonia were most luxuriant of all. This last result is what might be expected, (and it agrees well with the theoretic views of later chemists,) inasmuch as carbonate of ammonia is made up of carbon, oxygen, hydrogen, and nitrogen: all of which are essential to the supply of the additional quantities artificial plants require beyond that they can naturally obtain from the surrounding atmosphere. He observes that the solution of *nitrate of ammonia* seemed to be of no greater use than *rain-water*, and he attributes its failure to the circumstance of the acid being in excess. But Sir Humphrey was not aware that rain-water actually contains ammonia; it was left to the genius of Liebeg, in our later day, to develope that discovery.

CHAPTER XI.

Of the Composition of Productive Soils, and of the Agency of the Elements in their Natural Formation, from the Rocks upon which they rest.

We may now take it for granted that every practical farmer will admit the position as proved, namely, that there must be an exact adaptation and fitness between the condition of any given soil and the plants intended to be raised upon it: and that, if this condition does not exist naturally, it not only may be, but must be, artificially remedied.

At this stage of the inquiry, it will be our endeavour to anticipate further question, and to give an exact account of the chemical constitution of such soils as are known to be best suited to the cultivation and growth of green as well as corn crops.

There are in existence as many varieties of soils as there are species of rocks exposed at the surface of the earth. In fact, there are many more. Independently of the changes produced by cultivation and the exertions of human labour in tearing down and breaking up the surface, the materials of various layers have been mixed together and carried from place to place by various great alterations that, during a succession of ages, have been silently yet constantly carried forward in the system of our globe, together with the united agencies of air, water, and the varying alternations of summer's heat and the cold of winter.

It may not be improper here to give a general description of the *geological* constitution of Great Britain and Ireland. It will be impossible to avoid the use of some names which scientific men have imposed upon the various rocks; and indeed, if we could offer the names by which they are vulgarly and popularly known in each district, it is probable they would be equally unintelligible in distant parts of the country. From these rocks are formed, by the action of the elements, the various soils which support vegetation. *Granite* forms the great ridge of hills extending through Cornwall and Devonshire. The highest rocks in Somersetshire are limestone and grauwacke. The Malvern hills are composed of granite, sienite, and porphyry. The highest mountains in Wales are chlorite, schist, or grauwacke. Granite occurs at Mount Sorrel in Leicestershire. The great range of mountains in Cumberland and Westmoreland are porphyry, chlorite, schist, and grauwacke; but granite occurs at their western boundary. Throughout Scotland the most elevated rocks are granite, sienite, and micaceous schist. No true secondary formations are found in South Britain, and no basalt south of the Severn. The *chalk district* extends from the western part of Dorsetshire to the eastern coast of Norfolk. The *coal formations* abound in the district between Glamorganshire and Derbyshire, and likewise in the secondary strata of Yorkshire, Durham, Westmoreland, and Northumberland. Serpentine is found only in three places in Great Britain: in Cornwall, Aberdeenshire, and Ayrshire. Black and gray marble is found in Cornwall, and other coloured primary marbles exist in the neighbourhood of Plymouth. Coloured primary marbles are abundant in Scotland. The principal coal formations in Scotland are in Dumbartonshire, Ayrshire, Fifeshire, and in Sutherland. Secondary limestone and sandstone are found in most of the low countries north of the Mendip hills.

In Ireland there are five great associations of primary mountains; the mountains of Morne in the county of Down; the mountains of Donegal; those of Mayo and Galway; those of Wicklow and those of Kerry. Who does not remember the words of the song,—

> "The Wicklow hills are very high,
> And so's the hill o' Howth, Sir."

The rocks composing the first four of these mountain-chains are principally granite, gneiss, sienite, schist, and porphyry. The mountains of Kerry are chiefly constituted by granular quartz, and chlorite schist. Coloured marble is found near Killarney, and white marble on the west coast of Donegal. Limestone and sandstone are the common *secondary* rocks found south of Dublin. In Sligo, Roscommon, and Leitrim, limestone, sandstone, shale, iron-stone, and bituminous coal are found. The northern coast of Ireland is principally basalt; this rock commonly reposes on a white limestone, containing layers of flint, and the same fossils as chalk; but it is considerably harder than that rock. The stone-coal of Ireland is principally found in Kilkenny, associated with limestone and grauwacke.

To attempt to class soils with scientific accuracy would be a needless labour; the distinctions adopted by farmers are sufficient for our present purpose, particularly if some degree of exactitude be maintained in the application of terms. A full knowledge of modern geology is not necessary to enable a man to determine whether a field is best suited for arable or grazing purposes; nor is it our intention needlessly to employ the scientific appellations which would only puzzle because they are incomprehensible to minds unfamiliar with geological nomenclature. The expression "*a sandy soil*," is well understood; but let it never be applied to any soil that does not contain at least three parts out of four of sand. Then, again, sandy soils that effervesce or give off carbonic acid, or fixed air, when vinegar or vitriol is poured upon them, should be distinguished by the name of "*sandy limestone soils*," to mark them from sandy soils that contain silex or the earth of flint. The term "*clayey soil*," should not be applied to any land which contains less than one-sixth of an earthy matter not effervescing with acids; while the word "*loam*" should be limited to such soils as contain one-third of a smooth earthy matter, *considerably* effervescing with acids. A soil to be considered "*peaty*" ought to contain at least one-half of vegetable matter.

Soils perform at least *three* functions in reference to vegetation. They serve as a basis in which plants may fix their roots and sustain themselves in the erect position—they are the medium through which the greater part of the inorganic matter of vegetables is supplied to them during their growth—and they allow many chemical changes to take place that are essential to a right preparation of the various kinds of food which are yielded to the growing plant.

The best NATURAL SOILS are those whence the materials have been derived from the breaking up and decomposition, not of one stratum or layer, but of many—divided minutely by air and water, and minutely blended together: and in improving soils by artificial additions, the farmer cannot do better than imitate the processes of nature.

We have spoken of soils as consisting mostly of *sand*, *lime*, and *clay*, with certain saline and organic substances in smaller and varying proportions; but the examination of the ashes of plants shows that a *fertile* soil must of necessity contain an appreciable quantity of at least *eleven* different substances, which in most cases exist in greater or less relative abundance in the ash of cultivated plants; and of these the *proportions* are not by any means immaterial.

The labour requisite for the permanent improvement of land is repaid by correspondent advantage: the materials for the necessary adjustment are seldom far distant. If coarse sand be requisite, it is mostly or often found immediately over the chalky soil that needs it; and beds of sand and gravel are common below clay. Capital laid out in this way, secures for ever the productiveness and consequent value of the land.

In ascertaining the composition of barren soils with a view to their productiveness, or of partially unproductive land, in order to its amendment, they should be compared with fertile soils in the same neighbourhood, and in similar situations; as the difference of composition will, in most cases, indicate the proper methods of improvement. For instance, if on washing a portion of sterile soil it be found to contain largely any salt of iron, or any acid matter, it may be ameliorated with quicklime, which removes the sourness, or, in other words, combines with and neutralizes the acid. For though pure fresh burnt caustic lime is injurious to vegetation, yet in combination with acids (as in chalk) it proves eminently serviceable. A soil, apparently of good texture, was put into the hands of Sir Humphrey Davy for examination, said to be remarkable for its unfitness for agricultural purposes; he found it contained sulphate of iron, or green copperas, and offered the obvious remedy of top-dressing with lime, which decomposes the sulphate. So if there be an excess of lime, in any form, in the soil, it may be removed by the application of sand or clay. Soils too abundant in sand are benefited by the use of clay or marl, or vegetable matter. To a field of light sand that had been much burnt up by a hot summer, the application of peat was recommended as a top-dressing; it was attended not only with immediate advantage, but the good effects were permanent. A deficiency of vegetable or animal matter is easily discoverable, and may as easily be supplied by manure. On the other hand, an excess of *vegetable* matter may be removed by paring and burning, or by the application of *earthy* materials. The effect of paring and burning is easily understood. The matted sods consist of a mixture of much vegetable with a comparatively small quantity of earthy matter; when these are burned, only the *ash* of the plant is left, intimately mixed with the calcined earth. To strew this mixture over the *exposed* soil is much the same as dressing it with peat or wood-ashes, the beneficial effects of which upon vegetation are almost universally recognised. From what has been already said, it will be easily evident, that the beneficial effect of the burnt ash is chiefly owing to the ready supply of *inorganic* and saline material it yields to the seeds which may afterwards be scattered there; besides which, the roots of weeds and poorer grasses, if not exterminated by the paring, are so far injured as to lead to their death and subsequent decomposition.

The improvement of *peats* or *bogs*, or marsh lands, must be preceded by DRAINING, stagnant water being injurious to all the nutritive classes of plants. Soft black peats, when drained, are often made productive by the mere application of sand or clay as a top-dressing. *The first step to be taken, in order to increase the fertility of nearly all the improvable lands in Great Britain, is to* DRAIN *them.* So long as they remain *wet* they will continue to be *cold.* Where too much water is present in the soil, that food of the plant which the soil supplies is so much diluted and weakened that the plant is of necessity scantily nourished. By the removal of the superfluous water, the soil crumbles, becomes less stiff and tenacious, air and warmth gain ready access to the roots of the growing plant; the access of air (and consequently of the carbonic acid which the atmosphere freely supplies) being an essential element in the healthy growth of the most important vegetable productions. Every one knows, that when water is applied to the bottom of a flower-pot full of soil, it will gradually find its way to the surface, however light that soil may be; so in sandy soils or sub-soils in the open field. If water abound at the depth of a few feet, or if it so abound at certain seasons of the year, such water will rise to the surface; and as the sun's heat causes it to dry off, more water will rise to supply its place. This attraction from beneath will always go on most strongly when the air is dry and warm, and so a double mischief will ensue: the soil will be kept cold and wet; and instead of a free passage of air downwards about the growing roots, there will be established a constant current of water upwards. Of course, the remedy for all this is an *efficient system of drainage.*

In general, the soils which are made up of the most various materials are those called *alluvial*, which have been formed from the depositions of floods and rivers. Many of these are extremely fertile. Soils consist of two parts; of an *organic* part, which can readily be burned away when the surface-soil is heated to redness; and of an *inorganic* part, which remains fixed in the fire, consisting of earthy and saline substances; from which, if carbonic acid, or any elastic gas be present, it may, however, be driven by the heat. The *organic* part of soils is derived chiefly from the remains of vegetables and animals which have lived and died in and upon the soil, which have been spread over it by rivers and rains, or which have been added by the industry of man for the purposes of increased fertility.

This *organic* part varies much in quantity, as well as quality, in different soils. In peaty soils it is very abundant, as well as in some rich long cultivated lands. In general, it rarely amounts to one-fourth, or 25 per cent., even in our best arable lands. Good wheat soils contain often as little as eight parts in the hundred of organic animal or vegetable matter: oats and rye will grow in a soil containing only 1½ per cent.; and barley when only two or three parts per cent. are present. In very old pasture-lands, and in gardens, vegetable matter occasionally accumulates so as to be injurious, and overload the upper soil. This decaying vegetable, or animal matter, is the "humus" previously adverted to, and incorrectly supposed, before our day, to afford almost the sole *nutriment* essentially necessary to growing plants. That living plants derive from the remains of their decayed predecessors the advantage of being placed in contact with the *inorganic* or saline materials those plants once contained, is not to be denied. But unless the whole crop were ploughed in, every year, this quantity would be exceedingly minute. The true value of green crops ploughed into the soil, or of decaying vegetable matter, the "humus" of former writers, is the formation of *carbonic acid* by the combination of decomposed carbonaceous or woody fibre with atmospheric oxygen; thus supplying to the new and young roots carbon in a form susceptible of being taken up by them.

The *inorganic* portion of any given soil is again divisible into two portions—namely, that part which is *soluble* in water, and, therefore, in a state easily susceptible of being taken up by the vessels of a growing vegetable, and of a further and much more bulky portion which is *insoluble* in water. The *soluble* portion consists of *saline* substances —the *insoluble*, of *earthy* materials.

A *single grain* of saline matter in every pound of a soil a foot deep, is equal to 500 pounds in every acre, which is more than is carried off from the land in the course of forty years, supposing that the wheat and barley are sent to market, and the straw and green crops are regularly returned to the soil in the shape of manure.

Sprengel, a German chemist, now at the head of the Prussian agricultural school, whose own taste, as well as his professional duty, have long directed his attention to scientific cultivation of the soil—has published an exact analysis of two varieties of *productive* soil, of which the following is an abstract:

The first is a very fertile alluvial soil from East Friesland, formerly overflowed by the sea, but for sixty years cultivated with corn and pulse *without manure.*

The second is a fertile soil near Gottingen, which produces excellent crops of clover, pulse, rape, potatoes, and turnips; the two last more especially *when matured with gypsum.*

One thousand parts of each of these soils, after washing, gave—

	No. 1.	No. 2.
Soluble saline matter,	18	1
Fine earthy and organic matter, (clay)	937	839
Siliceous sand,	45	160
	1000	1000

The most striking distinction presented by these numbers is the large quantity of *saline* matter in the first variety. It consisted of common salt, muriate of potash, the sulphates of potash, gypsum, magnesia, and iron, with phosphate of soda, and other salts. The presence of this comparatively large quantity of these different saline substances, originally derived, no doubt, in great part from the sea, was probably one reason why it could be so long cropped *without manure.* Its composition illustrates the truth of the statement, that a considerable supply of ALL the species of inorganic materials is necessary to render a soil eminently fertile. Not only does this soil contain a comparatively large quantity of the soluble saline matters above enumerated, but it contains also 10 per cent. of *organic* matter, and some lime. The potash and soda, and the several acids, are also present in sufficient abundance.

In the second instance, a fertile soil, but which *could not dispense with manure*, there is *little soluble saline matter;* and in the insoluble portion, only traces of potash, soda, and the important acids. It contains, also, 5 per cent. of organic matter, and 2 per cent. of lime, which smaller proportions, together with the *deficiency of alkalies*, remove this soil from the most *naturally* fertile class, to that class which is susceptible in hands of ordinary skill, of being *brought to*, and *kept in* a very productive condition.

Sir Humphrey Davy examined some *productive* soils, which were very different in their composition.

We will state the analysis of a few of them.

Soil from Holkham, Norfolk, described as a "*good turnip soil*," contained 8 parts out of 9 of *siliceous sand;* that is, sand with flint earth, or silex: the remaining 1-9th part consisted, in every 100 grains, of—

Carbonate of lime, (chalk)	63 grains.
Pure silex,	15 grains.
Pure alumina, or the earth of clay,	11 grains.
Oxide (rust) of iron,	3 grains.
Vegetable, and other saline matter,	5 grains.
Moisture and loss,	3 grains.
	100

Thus the whole amount of *organic* matter in this instance is only 1 part in 200, or one-half per cent.; a fact which, in itself, would demonstrate the fallacy of supposing that decomposed animal and vegetable matter in the soil form the exclusive supply to growing plants.

In another instance, soil was taken from a field in Sussex, remarkable for its growth of flourishing oak trees. It consisted of 6 parts of sand, and 1 part of clay and finely-divided matter. One hundred grains of it yielded, in chemical language—

Of silica, (or silex)	54 grains.
Of alumina,	28 grains.
Carbonate of lime,	3 grains.
Oxide of iron,	5 grains.
Vegetable matter in a state of decomposition,	4 grains.
Moisture and loss,	6 grains.
	100

To *wheat soils*, the attention of the practical farmer will be most strongly directed. An EXCELLENT wheat soil from West Drayton, in Middlesex, yielded 3 parts in 5 of siliceous sand; and the remaining two parts consisted of carbonate of lime, silex, alumina, and a minute proportion of decomposing animal and vegetable remains.

Of these soils, the last was by far the most, and the first, the least coherent in texture. In all cases, the constituent parts of the soil which give tenacity and stiffness, are the finely-divided portions; and they possess this quality in proportion to the quantity of alumina (or earth of clay) they contain. A small quantity of this finely-divided matter is sufficient to fit a soil for the growth of turnips, or of barley, as turnips will grow (though it is not to be expected they will thrive) on a soil containing **11 parts** out of 12 of sand. Sand in much greater proportion, or rather disproportion, produces sterility. So pure alumina, or pure silex, pure chalk, or magnesia, are incapable of supporting vegetation; and no soil is fertile that contains 19 parts out of 20 of *any* one of the materials that have been mentioned.

Sprengel gives also the analysis of an *unproductive* soil from Luneburg. It contained, in 1000 parts—

Soluble saline matter, ...	1 part.
Fine earthy and organic matter, (clay) . .	599 parts.
Siliceous sand, ...	400 parts.
	1000

This unfruitful soil, compared with the analysis given of the other two on a previous page, will be found to be the lightest of the three, containing 40 per cent. of sand. But this alone is not enough to account for its barrenness,—many light soils containing a *larger* proportion of sand, and yet sufficiently fertile. One thousand parts of its fine earthy matter contain 40 of organic matter instead of 97,—778 of silica instead of 648,—91 of alumina instead of 57,—4 of lime instead of 59,—1 of magnesia instead of 10,—81 of oxide of iron instead of 61; while potash, soda, ammonia, chlorine, sulphuric acid, phosphoric acid, carbonic acid, are entirely wanting; such being the ingredients and quantities in 1000 parts of the finer portion of the *very fertile* soil from East Friesland. The oxide of iron is *in excess* in the Luneburg barren soil; there requires, therefore, to be added, not only those substances of which it is destitute, but such other matters as shall prevent the injurious effects of the excessive proportion of iron. This illustration may serve to aid the practical farmer in comprehending how far exact chemical analysis is fitted to throw light upon the capabilities of soils, and to *direct* agricultural practice. The *constitution* of a *soil*, like the *constitution* of a *horse*, or a human being, requires to be known and understood, if we would prescribe otherwise than at random, expensively, unprofitably, or injuriously, either for the diseases of the one, or for the deficiencies of the other.

The *varying* power of soils to absorb and retain water from the air, is much connected with their fertility. Sir Humphrey Davy has remarked upon this; and connecting his statement with the fact, that rain-water always contains ammonia, and, consequently, *nitrogen*, (as one of the elements of ammonia,) we can easily understand why it should be so. He observes, that "the soils which are most efficient in supplying a plant with water by absorption and retention from the atmosphere, are those in which there is a due mixture of *sand*, finely divided *clay* and *chalk*, with some animal and vegetable matter; and yet so loose and light, as to allow the action of the air beneath the surface." Sand in excess destroys the requisite stiffness of the soil, but gives little absorbent power.

The *absorbent* power of land is always greatest on the *most fertile* soils, thus affording one ready test of productiveness. One thousand grains of soil, rendered perfectly dry by exposure to heat equal to that of boiling water, ought, by exposure to air, saturated with moisture, to gain in weight, at least 18 grains, or one-fiftieth; so that the standard of fertility of soils for different plants must vary with the *climate*, (as well as the varying constitution of the soil itself,) and be particularly influenced by the *quantity* of *rain* that falls upon it. The power of soils to absorb moisture ought to be much greater in warm or dry countries, than in cold, marshy places; and the quantity of clay they contain, greater. The inference is obvious: if deficient, it ought to be added. Soils, also, on the slope of a hill, ought to be more absorbent than in plains, or in the bottom of valleys. Their productiveness is also much influenced by the nature of the sub-soil on which they rest; for, when soils are immediately situated upon a bed of rock or stone, they dry sooner by the sun's agency, than when the sub-soil is clay or marl. A prime cause of the fertility of the land in the *moist* climate of Ireland is, that happily the surface-soil rests upon a rocky substratum. A clay sub-soil will sometimes be of material advantage to a sandy upper-soil, inasmuch as it will retain the necessary moisture in such a manner as to be capable of supplying that lost by the earth above in consequence of evaporation. In the same way, a sandy or gravelly sub-soil often corrects the imperfection of *too great* a degree of absorbent power in the true soil.

In devoting the different parts of an estate to the necessary crops, it is perfectly evident that *no general principle* can be laid down, except when all the circumstances of the nature, composition, and situation of the soil and sub-soil are accurately known.

Whatever be the specific variety of the surface-soil, it will, of necessity, take its character from the prevalent substratum. In limestone countries, where the surface is a species of marl, the soil is often found only a few inches above the limestone, and its fertility is not impaired by the nearness of the rock: though, in a less absorbent soil, this situation would occasion barrenness; and the sandstone and limestone hills in Derbyshire and North Wales may be easily distinguished at a distance in summer by the different tints of their vegetation. The grass on the sandstone hills usually appears brown and parched, that on the limestone hills flourishing and green.

Each locality will continue to present to the agriculturist facilities for the cultivation of such vegetables as it is best fitted to raise, and for an indefinite period; that is, until the exhaustion of its saline materials, its capability will continue. In clayey soils, it will continue longest; because, as previously explained, *all clays contain potash* and *soda*. But even these in time are exhausted. Air, water, and the changing temperature of the seasons, are at the same time preparing a remedy for the coming deficiency. Fresh surfaces of broken, crumbling rock are in a state of continual formation, exposing to the elements the saline treasures they contain. A period will arrive in the history of all soils, when, *if their saline constituents are not artificially replaced*, it will be necessary, either by deep ploughing, or other mechanical modes of breaking up and exposing the rock from which that soil has been formed, to obtain a fresh supply of soluble alkalies. When the surface of a granite rock has been long subjected to the action of air and water, the lime and the potash it contains are acted on by both; the felspar, mica, and quartz, of which that rock is compounded, are decomposed. The felspar, which is, as it were, the cement of the stone, forms a fine *clay;* the mica, partially decomposed, mixes with it as *sand;* and the undecomposed quartz appears as gravel, or coarse sand, of different degrees of fineness. Then, as soon as the smallest layer of earth is formed in this way, the seeds of mosses, and other imperfect vegetables constantly floating in the atmosphere, and which have made that spot their resting-place, begin to vegetate: their annual reproduction and death furnishes a certain quantity of organizable matter, which mixes with the earthy materials of the rock. In this improved soil, more perfect plants are capable of subsisting, the gradual process being, in truth, an epitome of the world's original creation. Fossil geology shows us that such was the process; and that not until a soil was formed by the decay of reeds and mosses, was the earth's surface fitted to rear the stately oak. With every fresh disintegration of the surface, successive quantities of alkaline materials are presented to the growing vegetable.

CHAPTER XII.

Of the Chemical Analysis of Soils, and how far this is practicable by the Farmer.

Enough has been already written to show what is essential to the production of heavy crops, and to prove that a naturally good soil can be forced, or an inferior soil amended, only by the addition of such substances as are really requisite in each particular instance; such adaptation, of course, pre-supposing an exact acquaintance with the nature of the land.

But the practical farmer will anticipate the inquiry, How am I to arrive at this knowledge? I am no chemist: I can form some general notion of the composition of the soil which I cultivate; and, from experiments, (some of which have been fortunate, others confessedly expensive and unproductive,) I am enabled to say what seems to agree best with it. Is it necessary to employ a scientific chemist to analyze my wheat soils, or are the means of discovery within my own power?

In reply to such very natural inquiries,—to a certain extent, the means of analysis are within the reach of every working farmer. Nevertheless it is perfectly true, that the management and tilling of the soil is a branch of practical chemistry; and like the arts of dyeing, calico printing, or the smelting of metals, it may advance to a certain degree of perfection,—its present condition, (which has been stationary and imperfect for many centuries,)—without the aid of science; but it can only have its processes explained, and be led on to *shorter*, more *economical*, more *productive*, and *perfect* processes, by the aid of scientific principles.

From the analysis of Davy and Sprengel, already given, of soils known to be eminently productive, (and two or three such illustrations are as good as a thousand,) it is not difficult to say of what materials a good wheat soil *ought* to consist. It is impossible to compare any given soil with these standards, unless we have a similar examination instituted; and if it can be obtained from the hands of an able investigator, it is always very desirable, so much so as amply to repay the trifling expense. Chemistry has rendered many and great services to agriculture, and can render more: the two sciences ought not to be considered as having no relation to each other; on the contrary, practical farming is only conducted on *rational* principles when directed by chemical science. Hitherto, it has fallen in with the humour or bias of only a few scientific men to enter upon such inquiries. Sir Humphrey Davy, the greatest chemist of his age, devoted his efforts not only laboriously, but most usefully, to the prosecution of agricultural chemistry; and the recent views and discoveries of Liebeg, will do much to *economize* agricultural operations, as well as to direct the farmer to the easiest and shortest modes of doubling his crops. But generally, the appreciation of such efforts, on the part of learned men, has been so small—the reception of scientific results and suggestions by the farming tenantry, so ungracious, that little wonder can exist that so many have quitted the field in disgust—that the majority of able chemists should studiously avoid it. Hence it has happened that in England, the analysis of soils has rarely been undertaken, except as a matter of professional business. Exact chemical analysis is a difficult art, one which demands much knowledge and skill in practice. It calls for both time and perseverance, if valuable, trustworthy, and *minutely correct* results are to be obtained. But it is only by aiming after such *minutely correct* results that chemistry is likely to throw light on the peculiar properties of those soils, which, while they possess much general similarity in appearance, are yet found, in practice, to possess very different agricultural capabilities.

Sir Humphrey Davy has given, with his usual precision, very copious directions for the analysis of soils. But we have no hesitation in affirming, that few practical farmers are likely to attempt the task. Not that the requisite instruments are either numerous or expensive, but that some familiarity with chemical operations is necessary; and that little dependence could be placed upon results which, if incorrect, would mislead perhaps more widely than the merest guesses. Fortunately there are to be found men of ability in sufficient numbers to supply the requisite information; and there is nothing more inconsistent in soliciting from a practical chemist a statement as to the actual composition of a given portion of soil, with a view to the supply of its deficiencies, than there is in employing a veterinary surgeon not only to give an opinion as to the nature of the ailment of a horse, but to advise the appropriate remedy.

Undoubtedly, the utility and necessity of such interference or assistance may sound strangely—grate harshly upon the long-established usages of that class of English farmers with whom, unfortunately, mere *exertion* is a virtue, and skill or science a presumed apology for laziness. It would appear however, that in some agricultural districts, a spirit in most rational conformity with such combinations of science with mere brute labour, is beginning to prevail. Early in the present year, a meeting of landed gentry and farmers took place in Edinburgh, for the express purpose of forming an association *for the application of chemistry to agriculture;* a tolerably expressive indication of the state of public feeling in Scotland, and one that, we trust, will be followed up by the organization of kindred institutions throughout the entire kingdom. The great and leading object of the association is to have a chemist of first-rate eminence, resident in Edinburgh, who, during the winter months, shall devote himself to analyzing such soils, manures, and other substances as may be sent him by farmers, and giving them advice regarding their value and usefulness. In summer he will visit different districts of the country, at the request of members of the association, and give a few lectures in the towns, or advice to individuals, regarding the system of management best suited to different soils. It is easy to see that all this will be attended with very great practical benefits to the country.

We are aware, however, that there are persons who have a distrust of the aid to be had from chemistry in the delicate and refined processes of agriculture; and to them we would address a few words.

Now, the more recondite principles of vegetation are subjects on which neither chemist nor farmer will require to touch, Indeed, *there will be no call made on the farmers, or persons wishing the analysis, for any chemical knowledge.* They are to submit limestones, bone-dust, guano, and manures of all kinds, marls, decaying rocks, and such like substances, to the chemist, and he is to pronounce on their value, and to point out their utility in reference to different soils, and for raising different crops. He will say, for example, whether the guano has been robbed of its ammonia, or the bone-dust of its gelatine, or whether the limestone be coloured with bituminous matter which will disappear with burning, or with iron which will not; and then he will be able to say what price the article ought to bear, and with what crops, on what soils, and at what periods it ought to be used. On the part of the person who sends the substance for analysis, it is plain that no knowledge of chemistry is required; and even the chemist will not find his duty an arduous one. A few chemical tests, and an accurate balance, will be nearly all that he will require; and he will have no occasion to approach those nice and subtile operations of nature, over which there certainly hangs a delicate and almost impenetrable veil.

But the summer duties of the chemist will be even more important than the analysis which are to occupy his winter hours. During that season he will impart information on many of the more recent discoveries and improvements in practical agriculture; and already enough has been done to admit of his giving much valuable and curious information, whether in the form of lectures, or by communicating with individuals. For example, the good effects of bone-dust, and of the phosphates generally, on peaty soils—of saline compounds for crops of hay on loams in trap districts—and of lime on granitic soils—may be mentioned, and they admit of explanation. They are noticed here as a proof of the advancement already made in this kind of knowledge. But much yet remains to be done; and besides giving information, it will be his duty no less to suggest experiments. He will give instructions to farmers to make trial of substances, *the composition of which is known and determinate*, on different soils, and with a variety of crops, accurately noting the weight of the produce, both in its dry and moist state. And who does not see that such trials, made on a diversity of soils, (for in this respect the experiments will have the advantage over any which the chemist could make himself on an experimental farm,) will furnish him with results from which he may possibly draw some general principle. This, again, may point the way to other trials and new discoveries; and so on without limit.

Need we say what will be the benefits of all this training and experiment? In the first place, there will be a gain to the country at large in the increased productiveness of the land; and in this those will be the first to share who first know of the new methods that will give them crops at a lower cost than their neighbours. And, in the second place, a spirit of intelligence and inquiry cannot fail to be diffused among our farmers, of which it will be difficult to estimate the value. Instead of blindly following in the old courses, they will have a pleasure in devising new ones, and will gradually raise themselves in the scale of being. And if it be true that even the mechanical arts will fall off, as De Tocqueville has admirably shown, if their principles are lost sight of, just as copies taken from copies decline at last from the original, much more will the fields of the farmer, changing in their composition with every crop that is taken from them, reward none at last but the intelligent and the skilful.

CHAPTER XIII.

Of Advertised "Fertilizers" for the Soil.

THE publication of more scientific and enlarged views respecting the nature of vegetable growth, has led to the attempt to furnish mineral compositions to meet the supposed deficiency of saline matters in the soil. Their inventors secure the secret of each such composition by a patent; in other instances they are left unprotected: nevertheless, it is a matter of no difficulty to say of what materials they chiefly consist. Now, there are such things as patent medicines, and, unquestionably, there is scarcely one of them that may not be good for some ailment or other. The mischief of such nostrums is, that they are recommended as *universal* specifics; they will cure every thing. As any one may read of the last new fashionable pills, that they have stood the test of thousands of trials, and proved efficacious in the removal of the direst and most diversified evils that can infest humanity; so of these agricultural specifics, it is said that "their efficacy has been submitted to innumerable tests since the ingredients were discovered; by which trials their utility has been amply demonstrated in *all* instances." Now, this is saying too much. Macassar oil may cause a luxuriant growth of hair; but rubbed upon a deal box, it will not convert it into a hair-trunk before the morning: and so a remedy, said to be *universally* useful, mostly proves (whether land or living creatures be the subject of experiment) of little use in *any* instance. In some cases that have fallen under our own notice, the guano, which these mineral manures were intended to supersede, has proved a far more strongly-fertilizing substance. And if there had been no deficiency of the materials of which guano is exclusively composed,—if purely saline and earthy, rather than animal matter, had been wanting, the balance of recommendation would undoubtedly have turned the other way. All this shows that it is folly to add to a soil any other matters than *precisely those which are exhausted* or deficient; and that this can only rationally be attempted after a close examination of the materials of which that soil is composed.

Let us suppose this is done, and that an artificial saline or mineral compost is judiciously and accurately put together, either to meet the deficiency, or added to a tolerably good soil to increase its fertility. The advantages of its use are not overstated in a recent pamphlet.

1*st*, It is cheap, compared with its value: a twenty shilling cask will supply an acre.

2*d*, It is light and easily carried, when compared with carting manure.

3*d*, It is suitable for small holders who cannot afford soiling, or keeping of cattle for making dung-heaps.

4*th*, It enables a tenant-at-will to take a good crop out of done-out land, if his landlord refuse to renew.

5*th*, It furnishes to barren land such food for plants as had been deficient; such defects of one or more substances being, *in general*, the cause of sterility.

6*th*, It enables the cultivator to extract ten times as much vegetable aliment for his plants from the soil, and from other manure, as they could otherwise, in most cases, yield.

This is the language of one who has devoted much time, talent, and energy to the task of improving the soil; and he believes there are no soils which may not be permanently fertilized by the mineral compost which forms HIS invention. Thus he speaks of its powers. But bearing in mind the remarks we have already made, every practical farmer must advance upon his own responsibility in making trial of its capabilities; the object of this work being, *not* the introduction of *advertised* artificial manures into the notice of the agricultural world, but rather the dissemination of those sound and rational views of the necessary *relations* between PRACTICAL FARMING and PRACTICAL SCIENCE, without which Agriculture must still lag behind the age, and, though the first and most important of all arts, remain for ever stationary.

THE END.