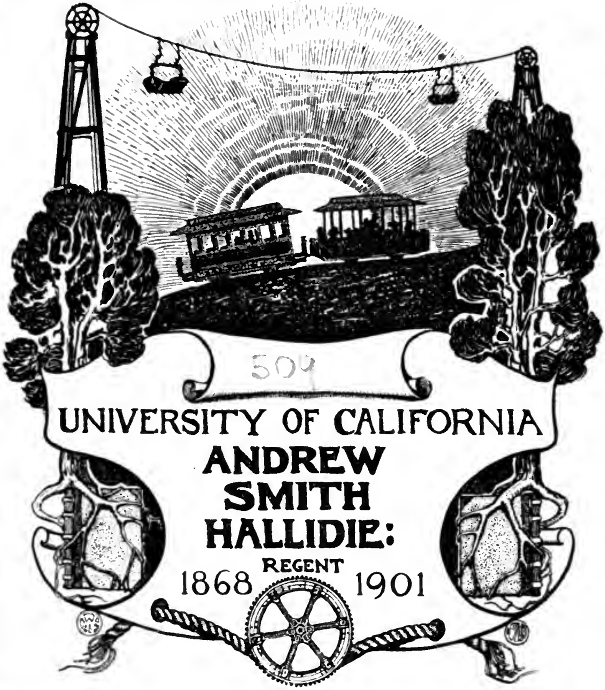
504
UNIVERSITY OF CALIFORNIA
ANDREW
SMITH
HALLIDIE:
REGENT
1868
1901

THE

FIRST BOOK

OF

LESSONS IN CHEMISTRY,

IN ITS

APPLICATION TO AGRICULTURE.

FOR THE USE OF

FARMERS AND TEACHERS.

BY

JOHN F. HODGES, M.D.

HONORARY MEMBER OF THE PHARMACEUTIC INSTITUTE OF NORTH GERMANY
FELLOW OF THE CHEMICAL SOCIETY OF LONDON, PROFESSOR OF
CHEMISTRY TO THE ROYAL BELFAST INSTITUTION,
AND TO THE CHEMICO-AGRICULTURAL
SOCIETY OF ULSTER.

LONDON:
SIMMS AND M'INTYRE,
13, PATERNOSTER ROW, AND 26, DONEGALL STREET,
BELFAST.

1848.

TO THE MEMBERS OF THE CHEMICO-AGRICULTURAL

SOCIETY OF ULSTER.

My Lords and Gentlemen,—

As you have afforded abundant proofs of zeal for the diffusion of agricultural knowledge, and as it is your efforts that have mainly contributed to promote that desire for more extended information in the scientific principles of their profession, which at present prevails among the farmers in the North of Ireland, I take the liberty of dedicating to you this little Work, which I trust may, in some degree, prove instrumental in rendering this knowledge more accessible to all classes of our countrymen.

I have the honour to be,

My Lords and Gentlemen,

Your most obedient servant,

JOHN F. HODGES.

Belfast, November 1, 1848.

CONTENTS.

ERRATA.

Page	37,	line	2	from	bottom, for *per cwt.* read *grains.*
,,	109,	,,	19	,,	top, for *and* read *as.*
,,	109,	,,	20	,,	top, for *as* ,, *and.*
,,	112,	,,	16	,,	top, for *and* ,, *or.*

PART I.

THE FIRST BOOK

OF

LESSONS IN CHEMISTRY,

IN ITS

APPLICATION TO AGRICULTURE.

FOR THE USE OF THE

FARMERS AND TEACHERS OF IRELAND.

INTRODUCTION.

The most striking characteristics of the present time are, the numerous applications which are every day made of the knowledge of the laws of nature, which modern science has so successfully investigated. During thirty years of peace the highest intellects of Europe have been dedicated to the advancement of the useful arts; and the discovery of new and refined instruments of research, by giving accuracy to the investigations of the philosopher, have not only enabled him to advance with confidence beyond the footmarks of his predecessors, but even to enter upon and subjugate regions hitherto considered as destined to remain inaccessible to human inquiry. Among the sciences, Chemistry in particular has, within the last few years, advanced with a celerity which even the most sanguine could not have anticipated; and it must be to us a matter of congratulation, that it is our fortune to live in an age in which the advantages of its brilliant discoveries are experienced by every individual. If we should estimate the value of any science by its effects upon the commerce and prosperity of nations,—by its influence upon the useful arts, and its contributions to the enjoyments of our race,—we must give the first place to Chemistry. If we cast our eyes around us, we everywhere observe this science originating new manufactures or improving old processes, giving to the physician his most powerful remedies in more manageable forms, and separated from injurious principles; in theoretical medicine substituting for the vague notions of the ancient physiologist clear and definite ideas of some of the most complicated processes of the human economy; instructing the dyer, the iron master, and the bleacher, and contributing in innumerable ways to advance the commercial greatness of the British empire, and to maintain the superiority of her manufactures.

The science of Chemistry has been cultivated from the most remote times, yet its history for centuries might be comprised in a few pages. At one time the slave of seekers for gold, and of dreamers after an elixir which might render man proof against the shafts of death, its language was rendered purposely obscure, so as to be unintelligible to the bulk of the people. In later times again we find it but the servant of the physician, useful in compounding the drugs which he employed, and exhibiting in its menial garb little of that important character which it has since assumed, and which leads us now to regard it as the surest interpreter of nature, and one of the most powerful instruments in advancing the civilization of the world. With the advance of scientific knowledge which has distinguished the present time, the means for diffusing it over the world have also everywhere increased. The railway, itself a noble monument of what the science of the present age has accomplished, has become one of the great instruments of extending the influence of her discoveries, and is destined to accomplish far greater things than the famous highways along which the arts and civilization of ancient Rome were carried, and will yet be the means of giving light and knowledge to the remotest corners of the land.

All professions have not been equally advanced by the application of scientific knowledge. Whilst some by availing themselves of its assistance have been brought to the greatest perfection, others have for years remained stationary, or have only lately received any impulse towards improvement. Among the occupations of men upon which science until very lately cast but a feeble and uncertain light, we must place the cultivation of the soil. It would occupy too much time to investigate all the causes of this strange state of things; it is, however, well known that the art of agriculture, the most ancient as it is the most important of human occupations, for centuries remained almost stationary and seemingly unaffected by the onward march of society.

Not many years ago all our knowledge of agriculture consisted of the loose notions handed down by tradition from father to son; mere experience was considered a sufficient guide, and every attempt to apply science to the investigation of the interesting phenomena of vegetation, and to the causes upon which the non-productiveness or fertility of a soil depends was sneered at by the farmer. By the great body of the farmers the remarks of the chemist were regarded as useless theories, and "book-farming" was considered as unworthy the attention of practical men. Within these few years, however, a great change has taken place in the disposition with which the application of science to agriculture was formerly regarded; and, what other arguments could not accomplish, the necessities of a rapidly increasing population, and the anxious struggle to render the produce of the soils of the country sufficient for their support, have been effectual in producing. In England and Scotland large sums of money were expended in the improvement of the mechanical condition of the soil; the field, unproductive from excessive moisture, was drained—new implements for breaking up and pulverising the heavy clay soils were invented—the thorough drain, the subsoil plough, and the clod crusher, were introduced and proved most valuable auxiliaries; places at one time considered hopelessly barren were brought into cultivation, and the hill sides were gradually covered with the nutritious grain. The introduction, first of bones and next of guano, and the advantages which followed their application, did much towards unsettling the traditional notions of the husbandman. But, after the use of bones had been continued for some years, it was found that their application was not uniformly successful; that in one field they produced luxuriant crops, but had scarcely any effect in another place. The effect of the application of guano was also observed to be different in different soils, and in some cases totally to disappoint expectation. In some parts of the country also, where lime, which had been introduced as a fertilizer, was applied, it was found nearly useless; while, in other districts again, its beneficial operation was most remarkable. In the uncertainty into which the farmer was thrown by such puzzling and apparently contradictory results, which threatened to interrupt the progress of improvement, he was induced to turn for assistance to

A 2

that science which he had at one time so obstinately rejected. It was fortunate that the extraordinary progress of Chemistry, and especially of Organic Chemistry,* enabled the chemist to investigate these important subjects, and to explain in a satisfactory manner the cause of the discordant results which attended the use of applications for the improvement of the soil. In this department of Agriculture the most valuable services have been rendered by Chemistry; and we may confidently anticipate, now that those who are interested in the cultivation of the soil are becoming fully aware of its intimate connexion with their pursuits, that it will lead to important improvements in the practice of Agriculture; and, by making the farmer acquainted with the nature of the materials upon which he has to operate, enable him to increase the produce of his farm, and introduce greater economy in the use of the manures employed in maintaining its productiveness. The investigation of the materials which enter into the composition of the plants cultivated by the farmer, and also of the soils in which they are produced in perfection, and of those which are distinguished by their unproductive character, has for several years been vigorously prosecuted by some of the most eminent chemists of Europe, and even already from these labours the most beneficial results have been derived. Amongst those whose researches have been most successful, we must assign the first place to that distinguished German philosopher, Baron Liebig of the University of Giessen, whose writings have contributed in so great a degree to direct the attention of the agricultural body both in England and in this country, to the important advantages to be derived from the application of scientific knowledge to their pursuits.

It is, however, only in England and Scotland that improved mechanical means and scientific knowledge have, to any extent, been applied to the improvement of the soil. I am glad to admit that the knowledge of the art of agriculture is, in many parts of this kingdom, rapidly progressing; but it is too true that in very few districts have the dormant energies of the soil been as yet called into proper activity by

* Organic chemistry is that department of science which investigates the composition of the parts of animals and vegetables, and of the various substances produced under the influence of life.

the application of those methods which, in the sister countries, have been found so successful in rendering large tracts of country, formerly considered incapable of profitable cultivation, productive of the richest crops.

Ireland is pre-eminently at the present time, and is probably long destined to continue, an agricultural country, and in her soil and situation is nobly endowed with all the conditions of fertility. It is, however, only of late years that agriculture appears to have been much regarded. The ancient inhabitants were occupied as hunters or shepherds; and the tillage of the soil seems to have received little attention even in comparatively modern periods, as, except in the rich *granges*, or farms of the religious houses, the wealth of the country, to a great extent, was in cattle and not in corn. Here and there, indeed, there might be a scanty patch of grain which served the chieftain for bread, but our wooded hills and broad plains exhibited for centuries but few traces of agricultural occupation. The productive powers of the soils of this country are most remarkable, and enable it, even with its present imperfect culture, to produce crops which excite the astonishment of the most skilful farmers of England and Scotland. This island also possesses, in its geological structure and genial climate, such advantages as to render it equal to any country in the world for the growth of plants and animals. May we not, therefore, conclude that it will yet be made to yield an amount of food far more than sufficient for rewarding the industry of any population which it will ever contain. But Providence has so decreed that the gold must be extracted with labour from the mine; not only bodily but mental exertion must be used to develop the resources of our soils. We must bring to the work the calculating but ardent zeal, and the patient industry and science-directed skill, which converted the once bleak and unprofitable fens of Lincolnshire and the heaths of the Lothians into rich and productive farms. Our farmers must not be unwilling to be taught, or to abandon practices, though sanctioned and confirmed by the examples of fathers and grandfathers, if more advantageous plans can be pointed out to them. Our old men must study the principles of their profession—the sons of our farmers must be educated not as if they were intended for the counting-house, the pulpit, or the bar, but to understand the composition of the fields and plants, upon the profitable cultivation of which they must depend for their subsistence and advancement in the world.

Much useful information, on the various departments of rural economy, has, within these few years, been accumulated in various parts of the world by the labours of men of science, to diffuse which among our farmers and landed proprietors, and to exhibit its application to the peculiar circumstances of this country, in language divested as much as possible of those scientific terms which appear so repulsive to ordinary readers, will be the object of these First Lessons. To assist in some degree in diffusing such knowledge among our countrymen, so as to promote that desire for improvement, which, after a long space of inactivity, is beginning to influence the public mind, I conceive to be a work worthy of the co-operation of all who take an interest in Ireland. To show that such a desire exists at the present time, it is only necessary to point to the agricultural schools which are springing up in so many localities—to the new spirit which has been awakened in the older educational institutions—to an institution established among the tenants and proprietors of our northern province, for the express purpose of making the farmer acquainted with the principles of his profession—to our valuable native journals, devoted exclusively to agriculture, and commanding a large circulation—all these things are gratifying evidences that, as a nation, we have begun to devote ourselves to the subjects which are best calculated to advance our prosperity and to earn for us the respect and esteem of other countries.

One great obstacle to the improvement of agriculture is the custom which yet too commonly prevails, of regarding it solely as an art, requiring merely a certain amount of practical skill for its successful prosecution; and, whilst the vitriol manufacturer, the bleacher, the sugar-refiner, and the dyer, are conducting their processes in strict accordance with certain scientific principles, and whilst every year new applications of chemical knowledge enable them to work with greater certainty and economy, the manufacture of food, by far the most important to human existence, has been left to the direction of men utterly unacquainted with either the materials upon which it is their business to operate, or the conditions required to render their work successful. Whilst in the factory and the manufactory not only the managers are familiar with all the processes of their art, but the workmen are carefully trained in the duties allotted to them, how few of our food manufacturers, from the cottier, whose little garden grows potatoes and cabbages, up to the proprietor whose farm of some hundred acres contains plants of different habits and requiring a variety of food and treatment, are yet in possession of that special knowledge which their occupation requires.

It has uniformly been found that, in all professions, the men who are most successful are those who have most carefully studied the principles of their business; and why should it be different with the agriculturist? There was, indeed, a time in the agriculture of this country when the virgin soil gave its fruits without much skill or intelligence being required for its cultivation; but that time has gone by, and our exhausted fields and increasing population require that the farmer, who desires to support himself by the profits of his produce, should make himself acquainted with the conditions upon which the successful cultivation of his various crops depends, so that he may increase the amount of food produced upon his farm at the least possible expense.

Let us suppose that the farmer is anxious to acquire a knowledge of the scientific principles of his art, his first step should naturally be to make himself acquainted with the nature of the materials upon which he operates, and of the plants which it is his object to raise. To acquire this knowledge he must have recourse to Chemistry. Observation shows him that the acorn springs up into the oak—that the seed of wheat is the parent of many stalks of grain—that plants flourish in certain circumstances, but decay in others; and that they are, therefore, dependent upon certain circumstances or conditions for their growth. They cannot, like animals, travel about in search of food—they are fixed to one little spot of ground; from whence, then, does the acorn obtain those materials which are moulded into the stately oak—whence does the tiny grain of wheat procure the substances to build up its tall and flinty straw, and its seeds stored with nutritious food? These are questions of great interest, and to which, until lately, it was not in the power of science to give satisfactory answers.

It is evident that there are only three sources from which plants can procure the materials for their support,—either from the air which is everywhere above and around them, from the water which exists in the air as vapour and descends from it producing rain, springs, and rivers, or from the soil in which they are fixed. In the infancy of science, when all our knowledge of these subjects was made up of conjectures, to each of these sources the duty of affording the essential food of plants was in turn attributed. We now, however, know that neither the air, the water, or the soil, is by itself sufficient to maintain the growth of the crops that we cultivate for food, but that they all unite in contributing to supply the simple elements, the raw materials, from which both the parts of vegetables and the nutritive matters which render them valuable to man are produced.

It must appear astonishing to those who learn it for the first time, that all the varied forms of rock and water, of plant and animal, presented to us in this world in which we live, so different in their appearance and properties, consist of no more than sixty-two different substances; and that of these only about fourteen are extensively employed in nature. These sixty-two substances have as yet resisted all the efforts of the chemist to procure from each of them more than one kind of matter:—thus, from iron, which is one of the number, we can procure nothing but iron. From this circumstance iron, and substances like it, which contain only one kind of matter, have been considered SIMPLE OR ELEMENTARY BODIES. If, however, we examine a piece of limestone rock, the soil from our fields, or the water which flows in our rivers, we find that they contain several distinct kinds of matter—that they are what are termed *compound* bodies. The variety of appearance which the elementary bodies present enables us to divide them into classes. Thus some of them, like iron and lead, are solids, while others of them are known as liquids; and others again, thin and invisible like the gas which illuminates our streets, are termed airs or *gases*. The elementary bodies are seldom found in a separate state;* gold and

* The majority of these elementary bodies are seldom met with in nature. The following list contains all those which it is essential for the agricultural student to remember, or the teacher to illustrate:—

Oxygen,	Sulphur,	Calcium,
Hydrogen,	Phosphorus,	Magnesium,
Nitrogen,	Carbon,	Aluminum,
Chlorine,	Silicon,	Manganese,
Bromine,	Potassium,	Iron;
Iodine,	Sodium,	

silver are indeed occasionally discovered in minute quantities, but the value attached to these substances is a proof that they constitute but a small portion of the forms of matter usually met with around us.

There is a constant tendency in nature to produce *compounds*. Expose a piece of bright iron to the air, and it is gradually covered with a reddish brown coating; and if we weigh it we find that it has increased in weight. It has in fact united with another simple body,* which is one of the constituents or elements of the air. It is the disposition which the elementary bodies possess of uniting together, that presents us with the apparently endless variety of forms of matter which we everywhere observe. When the farmer spreads upon his field the burned limestone which he has procured from the kiln it, though already a compound substance, becomes still more complicated in its composition. Like the iron, it unites with one of the ingredients of the air,† and at the same time increases in weight and experiences a material alteration in its properties; before its exposure to the air it was a hard, caustic‡ substance, but after that, it assumes the form of a mild powder, which experience has taught the farmer contributes to increase the fertility of his soils.

In the following chapters, my object will be to make the young farmer acquainted with so much of the characters of the elementary and compound bodies which we meet with in nature, as it is important for him to know, and also to point out to him such applications of this knowledge as may be useful to him in the practice of his profession. I trust that he will be induced to accompany me from the beginning, and diligently endeavour to obtain clear ideas of the various subjects which may be brought before him.

* Oxygen. (7.) † Carbonic acid. (20.)
‡ *Caustic*, capable of producing a burn.

LIST OF APPARATUS, ETC. TO BE PROCURED BY TEACHERS FOR THE PURPOSE OF EXHIBITING TO THEIR PUPILS THE EXPERIMENTS DESCRIBED IN THE LESSONS.

1. Two small retorts, or, instead of them, the flasks in which Florence oil is usually sold; these flasks may be purchased from the grocer, and, when fitted with good corks and bent glass or tin tubes, form excellent vessels for preparing gases.
2. A small spirit lamp for heating retorts, &c.; or, when it cannot conveniently be procured, a lamp sufficient for the purpose may be constructed by using a small bottle, such as an ink-bottle fitted with a cork, through which a piece of tin or glass tube is passed for holding the wick: cotton wick may be procured from the chandlers.
3. A stock of glass tubes, each about the thickness of a large quill, for bending over the spirit lamp, to form tubes for conducting gases, &c. may be purchased at the glass-house.
4. A holder for supporting retorts, &c. over the flame of the spirit lamp, may be formed from a piece of stout iron wire and a wooden stand, as represented in Fig. 1, or purchased.
5. Red and blue litmus papers, for testing acids and alkalies, may be purchased from a druggist.
6. Two slips of platinum foil, or, instead of them, slips of thin window glass.
7. Half-a-dozen glass rods, or, instead of them, narrow slips of window glass, will be required for stirring liquids, &c.
8. An apparatus for burning hydrogen gas may be formed from a piece of tobacco pipe passed through a cork, carefully fitted to a four-ounce vial.
9. Half a dozen test tubes of thin glass, or instead of them ale-glasses, for testing liquids.
10. A glass or porcelain funnel, and some sheets of white filtering paper.
11. A small porcelain mortar and pestle.
12. Apothecaries' scales and weights, which cost about 4*s.* 6*d.*
13. Half-a-dozen small vials with glass stoppers, containing 2 oz. sulphuric acid, 2 oz. muriatic acid, 1 oz. phosphorus, $\frac{1}{4}$ oz. caustic potash, $\frac{1}{2}$ oz. tincture of iodine, 4 oz. spirits of wine.
14. Half-a-dozen wide-mouth bottles with corks, containing 2 oz. black oxide of manganese, for the preparation of oxygen gas; 4 oz. chlorate of potash, 2 oz. carbonate of soda, 4 oz. metallic zinc in fine cuttings, 4 oz. charcoal in small pieces, 4 oz. carbonate of ammonia.

The above are all that are absolutely necessary. The list, however, may be extended at the pleasure of the teacher, and include specimens of the salts and artificial manures described in the lessons. The pupil may also be encouraged to collect specimens of the rocks to be found in the district in which the school is situated, which will form a most useful foundation for a school museum. A coloured geological map of the country should also have a place in every agricultural school.

CHAPTER I.

ACCOUNT OF THE MATERIALS FROM WHICH PLANTS ARE FORMED; MATERIALS EXISTING IN THE AIR.

1. I HAVE stated, that for the growth of our cultivated crops, the essential conditions are the air, the soil, and water. I say our cultivated crops, for it is familiar to us that a very large class of plants, the weeds which grow so luxuriantly in the sea that washes our coasts, and which, in some parts of the world, navigators tell us, cover many miles of the ocean, are wholly immersed in water, and derive no support from the soil. But, though the sea-weed can extract from the water all the materials required for its nourishment, I need scarcely say that the plants which we cultivate for food require a soil, as well as water and air, for their development. Such, therefore, being the sources from which the nutritive materials are derived that enable the seed to throw out its stalk and root, and to produce substances adapted for our use, it must be most interesting, and not without important practical advantages for the farmer, to understand something of the part which the air, the water, and the soil, severally perform in the nourishment of his crops. Fortunately, the advance of organic chemistry within these few years enables us satisfactorily to investigate many things connected with this subject, which, formerly, it would have been impossible to explain.

2. It will be evident that, before entering upon this inquiry, it is necessary that you should acquire a knowledge of the simple bodies or elements of which air, water, and the soil are composed, and of their properties; as, without becoming familiar with the materials upon which you have to act, you cannot expect that you should successfully employ them in regulating the development of vegetation. It will require no great exertion of mind to obtain this knowledge, and its possession will greatly facilitate your comprehension of those beautiful processes by which the life of plants and animals, and the harmony of creation, are maintained.

3. We will commence with the AIR OR ATMOSPHERE, as that great ocean of vapour which surrounds the earth is called, and in which both plants and animals live. This great mass of gases,* without the presence of which neither plant nor animal could exist, possesses very remarkable physical properties; but to these it is not necessary at present to direct your attention. We cannot see the air, but we feel it in the breeze which strikes upon us as we walk briskly along, resisting our progress; and we hear it sighing in autumn among the falling leaves, and howling in winter in the fierce wind which rushes through our valleys. You can easily convince yourselves that, though invisible, it possesses substance, by trying to press together the sides of an inflated bladder, and, when the bladder is compressed, if you pierce it with a pin, the air will rush out with force.† For our purpose, it will be necessary that we should consider the nature of the substances which compose the atmosphere, for it is not an elementary body, as the ancient philosophers taught, and as many uneducated people yet imagine, but formed by the mixture of several airs, which possess, when separate, the most energetic properties.

4. It may be useful in this place to explain the meaning of the term *mixture*, which I have just employed as distinguished from *chemical combination*, as these terms frequently occur in works which treat of the chemistry of agriculture. When we stir together a quantity of sand and common soda, such as is used in bleaching, we produce a mixture of these substances which partakes of the characters of both. We can at once perceive that it is a compound of sand and soda. If we place the mixture in boiling water, the soda will dissolve, and can be poured off with the water, leaving the sand unchanged. But if, after mixing the sand and soda, we place them in an iron or clay vessel, and expose them to a very strong heat, we produce a compound in which no trace of the

* Gases are thin, elastic, and invisible substances, of which the gas employed in illuminating towns is an example. Many of them have neither colour, taste, nor smell; but, though not to be detected by our senses, they possess most energetic and remarkable properties.

† ILLUSTRATION.—Attempt to fill a wide-mouthed bottle by placing it with its mouth downwards in a basin of water, and you will find that the water will not pass into it: something (the air) resists its entrance; but if you incline the bottle to one side, the air, being lighter than water, will escape in bubbles, and the water will enter and occupy its place.

sand can be observed, and which, according to the quantity of soda employed, either dissolves entirely in boiling water, or forms an insoluble transparent substance like glass.* These experiments afford us an example of the changes which the union of elements or compounds is capable of producing. In the first case, the new body produced by simply mixing the substances together partakes of the properties of its constituents. We can distinctly observe the sand and soda unchanged. But in the second case, when they *combine*, a body may be formed possessing properties and appearance totally unlike those of the substances employed to produce it. In the first case, the substances are said, as with the sand and soda, to be merely *mixed;* in the second, to be in *chemical combination.*

5. There is, also, another mode in which changes are produced in the form and appearance of the bodies around us, and to which I shall have frequent occasion to allude. Its operation is just the reverse of those which I have above described; for, instead of causing variety, by bringing bodies together in new forms, it separates or breaks up the compounds formed by nature. It acts as the lime-burner who places in his kiln the compound limestone, and, by means of heat, tears asunder its constituents, producing a substance possessing properties very different from those of the limestone rock of our hills. This process of change, which is continually going on around us, is termed *decomposition.* I will again return to its consideration.

6. Let us, however, continue our inquiry into the nature of that great mixture of gases with which we were engaged. (*a*) If you were to take some burning wood or coal, and attempt to kindle a fire, and at the same time close up the top of the chimney and the mouth of the fireplace, you would find that the fire would not burn. You must "give it air," or the lighted fuel would be extinguished. (*b*) If you were to place a healthy plant, growing in a pot, within a large, carefully closed bottle, and supply it only with dis-

* A soluble glass has been employed on the Continent as an application to paper and wood, in theatres and public buildings, to diminish the liability to take fire. It is best made by fusing together a mixture of 70 parts carbonate of potash (salt of tartar), 54 parts carbonate of soda, and 152 parts of ground flints or pure white sand. The glass produced will readily dissolve in water, and may be applied like a varnish.

tilled water, that is, water from which the air has been expelled by boiling, like the fire, it would soon die,—we must "give it air," or it will not flourish. (*c*) If we take a piece of wax taper, and fix it on a cork so as to allow it to float on a basin of water, and then light it and invert over it a large, wide-mouthed bottle, the taper will continue to burn for a short time, but will at last die out; and if we now cautiously introduce a second lighted taper into the bottle, it will be immediately extinguished. (*d*) If, instead of a lighted candle or a plant, we were to place in a closed bottle a mouse, or any small animal, it would live for only a short time, and the life of a second animal, introduced after the death of the first, would, like the light of the candle, be immediately extinguished. Air, therefore, undergoes a change by supporting the life of plants and animals, or the flame of a candle. It appears to contain something indispensable to both animal and vegetable life, and deprived of which it is incapable of feeding flame or supporting animal existence.

7. The air is thus proved to contain a substance remarkable for its influence in supporting life and flame. This substance seems to form but a small portion of its bulk and to be soon consumed. Such indeed we know from chemical investigation is the case, this substance being a gas, one of the simple bodies termed OXYGEN, which forms only about a fifth part of the atmosphere. This gas, besides forming a part of the air, is also locked up in immense quantities in combination with rocks and minerals, and by exposing some of these to heat, we can *decompose* them, in the same manner that the limestone is decomposed in the kiln, and drive off their oxygen so that we can procure it in a separate form,*

* As it is most desirable that the teacher should prepare small quantities of the gases described in the lessons, and illustrate their properties to his pupils, it will be useful to describe the apparatus and operations required for their preparation and collection. When a bottle is filled with water, as already described, it may be raised up in the water, and will remain full, provided its mouth be kept immersed. If we now plunge another bottle, in common language termed empty, but really containing air, into the water in such a manner as to allow the bubbles which escape to rise under the mouth of the bottle filled with water, the air will gradually drive out the water, and occupy its place. If we bring a bottle full of gas, or a tube from which it is escaping, under the mouth of a bottle of water as just described, the water will in like manner be driven out, and we will procure a bottle of the gas, which we may remove from the basin and preserve for

and examine its remarkable properties. In the air its amount is so small that its properties are not so striking.

examination, if we close it securely with a cork dexterously inserted, without raising its mouth above the surface of the water in the basin. A common wash-hand basin may be used for collecting gas; but a small trough formed of tin-plate, and provided with a shelf pierced with two or three holes, termed a pneumatic trough, is usually employed. Water is poured into this trough until it rises about an inch above the surface of the shelf, and when it is desired to collect the gas, a bottle full of water is placed with its mouth directly over one of the small holes, and under the same hole the tube from which the gas escapes is placed. The directions which we are about to give for the preparation of oxygen will now be understood without difficulty. Oxygen gas is one of the most extensively diffused bodies in nature, forming about a half of the crust of the earth, and being an essential ingredient of water and of the bodies of plants and animals. It is never met with, except in combination with other bodies, and the usual method of procuring it in a separate state is to apply a strong heat to certain substances which contain it in large quantity. Thus, by placing in a retort, or Florence flask fitted with a cork, through which a bent tin or glass tube passes, a mixture of two parts of Chlorate of Potash, with one part of black oxide of Manganese (49), both substances being previously rubbed to fine powder in a mortar, and applying heat to the vessel by means of a spirit lamp, the tube of the retort, or that attached to the flask, being placed as described under the mouth of a bottle inverted and full of water, the gas will escape through the tube, and expel the water from the bottle. The engraving will show the arrangement of the apparatus required.

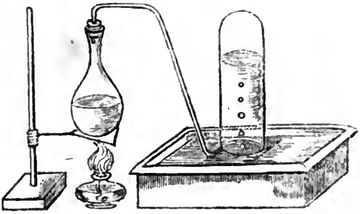

Fig. 1.

Illustration of the properties of Oxygen.

a. A tube may be filled with the gas, which will be found to possess neither colour, smell, nor taste. *b.* Into another tube filled with gas, and removed from the trough, by placing the thumb under water over its mouth, a bit of taper, with its flame just extinguished, may be introduced; the flame will immediately be rekindled, and burn with increased brilliancy, *but the gas will not itself take fire.* It is a supporter of combustion, but not itself combustible.

c. A piece of phosphorus about the size of a small pea, placed upon the iron spoon, may be ignited by touching it with a piece of lighted wood, and immediately introduced into a half-pint bottle of the gas. It will burn with a dazzling white light. When the quantity of oxygen in the atmospheric air is diminished 8 per cent, (Liebig), the latter becomes injurious to animal life, and incapable of supporting combustion.

Fig. 2.

Its presence, however, as we have stated, is indispensable for the support of life and flame (6). Thus, in the diluted state in which it exists in the air of our rooms, it gives our fires and candles the power to burn; by its influence the coal is slowly consumed, giving a comfortable warmth to our dwellings, and the tallow and the wax of our candles gradually burn, affording us a cheerful light. But when a candle or other ignited body is introduced into a vessel of pure undiluted oxygen, all the energy of its properties is displayed, the candle no longer burns quietly as in common air, and even though extinguished before being introduced, if a particle of its wick continues to glow, it will immediately burst into a vivid flame and be rapidly consumed. Even metallic bodies, which like iron are merely melted when exposed to our most intense fires, if heated in a vessel of this gas, burn with brilliant sparks.

8. When the oxygen gas which for a time supported the flame of a taper in the bottle of air is consumed (6 *c*), four-fifths of the latter remain behind, invisible like the air itself, but deprived, as we have stated, of those properties which render it capable of supporting flame and animal life. This substance, which forms the great bulk of the air, consists nearly altogether of a gas termed NITROGEN, which though incapable of supporting life when separated from oxygen, yet is one of the most essential ingredients of the flesh of animals, and of all those vegetable productions which serve as nutritive food.* Without the presence of some substance containing it, no plant could arrive at maturity, or produce any of those matters in their roots and seeds

* NITROGEN gas may be prepared by igniting a small piece of Phosphorus placed in a little cup, standing on a soup-plate half filled with water, and covering it with a confectioner's jar, or wide-mouthed bottle (*Fig.* 3). The burning Phosphorus unites with the oxygen of the air contained in the bottle, and the compound formed (a substance termed phosphoric acid) dissolves in the water contained in the plate, leaving the nitrogen gas of the air. Like oxygen, nitrogen is devoid of taste, smell, or colour. That it is *neither inflammable* nor *capable of supporting flame*, may be shown by introducing a lighted candle into the bottle. It is rather lighter than air.

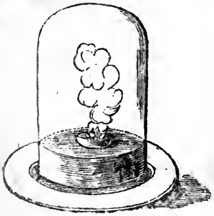

Fig. 3.

which render them valuable as food for man and the inferior animals.

9. The most singular character of nitrogen is the indisposition which it exhibits to enter into combination with other bodies. The other simple undecompounded bodies, like oxygen, &c. have a constant tendency to unite together, but resisting what appears to be a general law, this gas can with difficulty be forced into combination; so that it is considered that, as existing in the air, it serves merely to modify the energetic properties of oxygen, but takes no part in contributing to the formation either of plants or animals. How, then, is this element, which is so unwilling to unite with other bodies, and yet so indispensable to animal and vegetable existence, obtained by plants? This important question will be answered as we proceed.

10. In addition to oxygen and nitrogen, the preponderating ingredients of the atmosphere, there are invariably diffused through it exceedingly minute portions of two other gaseous bodies designated AMMONIA and CARBONIC ACID.* These bodies, though existing in the air in quantities which render them almost imperceptible, you will find are of the greatest importance, and may be regarded as pre-eminently required for the nourishment of plants. The first of these bodies, ammonia, is, like oxygen and nitrogen, a kind of air. It is, however, not like them simple, but has by the chemist been discovered to consist of two of the simple elements, one of them the unsocial element nitrogen, which we lately noticed, and which, in this compound, has united itself with a gas which we have yet to describe, named hydrogen. In ammonia, nitrogen loses all the inertness that distinguished it in its separate state, and takes under various forms a most active part in several important operations which I shall have occasion to notice.

11. Before proceeding further, it is necessary that you should understand the meaning of some terms which I will have occasion to employ, and which you will frequently meet in reading works on agriculture. You have probably observed

* Dr. Clarke gives the following statement, in round numbers, of the composition of the atmosphere:—

Nitrogen	1900	volumes.
Oxygen	500	do.
Carbonic acid	1	do.

that the kind of cabbage used to prepare pickles (red cabbage), which when growing in the garden is of a violet colour, becomes of a bright red when placed in vinegar. If you were to pour upon the cabbage leaves water mixed with a few drops of vitriol, or spirits of salts, precisely the same change of colour would be produced. Now substances which, like vinegar, vitriol, and spirits of salts, possess a sour taste, and alter the violet colour of cabbage leaves to a *red*, are termed *acids* by chemists; and strips of paper coloured by being dipped in liquids procured by boiling in water the leaves of the red cabbage, the common violet, or a certain blue vegetable colouring matter called litmus, are employed by them in their experiments, for the purpose of *testing* or ascertaining the presence of these substances.

12. When common potash, or the soda ash employed in bleaching, is dissolved in water, and *tested* by means of the prepared papers just described, the colour of the paper is not changed to red. On the contrary, if the paper be reddened by the action of an acid, and afterwards dipped in the solutions, its original blue colour will be restored.* To substances which like potash and soda ash possess a peculiar acrid, disagreeable taste, and restore the blue colour to reddened test-papers, chemists give the name of *alkalies*.

13. When acids and alkalies are mixed together in proper proportions, they enter into *chemical combination*, and form what are termed *neutral* compounds, in which neither acid nor alkaline characters can be detected. Thus the taste of vitriol, (sulphuric acid) is intensely sour, but if we gradually add to it potash, which is an alkaline substance, we can procure a compound in which neither by the taste nor the test-paper can we detect the characters which distinguished these substances before their union.† Such compounds of acids and alkalies are very numerous, and are designated *salts* by chemists, and receive a name derived from the ingredients

* When the blue liquid, obtained by steeping or boiling red cabbage or violets in water, is mixed with an alkaline liquid, as a solution of potash, soda ash, or ammonia, its colour is changed to *green*.

† The teacher may impress the nature of the change which is effected by chemical combination, upon the minds of his pupils by illustrating the properties of sulphuric acid and soda (soda ash) in their separate state, and as united in *sulphate* of soda (glauber salt), which compound exhibits no trace of the acid and alkaline characters of its constituents.

which exist in them: thus the compound of sulphuric acid with potash is termed *sulphate of potash.*

14. Though neither nitrogen nor hydrogen (which, I have said, unite together to form ammonia), in a separate state possesses smell or taste, the compound evolves the peculiar pungent odour of smelling salts, and is also distinguished from its elements by exhibiting the properties which I have described as characteristic of the class of bodies termed alkalies. It has a caustic alkaline taste, restores the blue colour of reddened test papers, and readily enters into chemical combination with acids, forming salts, several of which are employed as manures.

15. This singular pungent smelling gas has not been found, like oxygen, to enter to any great extent into the composition of rocks and minerals, but it is produced in large quantities in various natural processes. Thus it is formed in those great chemical operations which accompany volcanic eruptions, and is also evolved wherever animal or vegetable matters are exposed to a high temperature, or are undergoing that more gradual dissolution of their parts which we term decay. You may recognise its characteristic penetrating odour upon burning a piece of bone or a feather, and you may convince yourselves that the vapour is alkaline by bringing near it a slip of reddened test paper. It is given off by the liquid manure of the farm-yard, and you will detect its smell upon opening the door of an ill-ventilated stable, and in the neighbourhood of a carelessly managed manure heap.

16. Ammonia also differs from its elements by dissolving readily in water, and a strong solution of it is sold by the apothecary. From its solubility in water, the rain which falls upon the unprotected manure heap flows away laden with it, and in the sewer water of our towns, enormous quantities of it are swept into the sea which surrounds these islands. It has been calculated that in the water of a single sewer in London, upwards of a ton weight of ammonia is every day poured into the Thames.

17. In the distillation of coal to produce the gas used for lighting our cities, a liquid containing a very large amount of ammonia is formed, which is extensively used in the arts, and has also been employed with great advantage as a manure, under the name of "gas liquor." (*See Manures.*)

18. Ammonia is considerably lighter than common air; and

therefore, when the farmer perceives its penetrating odour near the manure-heap, or where guano has been stored, he may be certain that it is escaping into the atmosphere, and that, if neglected, these manures will gradually be rendered less capable of benefiting his fields. Chemistry teaches us how by very simple means, as will be hereafter described, this loss of ammonia may be prevented.*

19. Though Saussure, whose works contributed to direct the attention of philosophers to the substances which serve for the food of plants, suspected the presence of this gas in the atmosphere, it was reserved for that great chemist, whose writings may be said to have originated the modern theory of agriculture, to demonstrate its existence by experiment. Liebig, with his usual sagacity, reasoned that the difficulty of detecting the presence of ammonia must arise from the extremely minute portion of it which existed in the few cubic inches of air usually submitted to examination, and that we would more easily convince ourselves of its presence by operating upon some pounds of rain water; by which means we should obtain in solution, carried down with the rain, the whole amount of it diffused through several cubic feet of air. Accordingly, he collected rain water in the neighbourhood of Giessen, where he resides, when the wind was blowing in the direction of the town, so that the rain could not obtain any ammonia from the smoke, &c. Several hundred pounds of this water were boiled to dryness in a

* Ammonia is most conveniently prepared by introducing into a flask a mixture of one part of sal-ammoniac and two parts of quicklime, and applying a gentle heat. The substances must, previously to being mixed, be reduced separately to a fine powder. As ammonia is very soluble in water, it cannot be collected over the water trough, but bottles and tubes may be filled with it by fixing, by means of a cork, to the mouth of the flask, a tube of glass of sufficient length to pass to the bottom of the vessel used to receive the gas. When inverted over the tube (*Fig.* 4) the light gas will entirely expel the atmospheric air from the receiver. If you close the receiver and bring it over a vessel containing water, and withdraw the cork, the water will rush up with force, and unite with the gas. This experiment, when a large bottle of gas is used, and the water is mixed with some blue vegetable colour reddened by the addition of a few drops of vinegar, is exceedingly striking. The water rushes into the bottle, and its blue colour is restored by the alkaline gas. Water saturated with this gas is what is sold as liquid ammonia.

Fig. 4.

copper still, with the addition of a small quantity of muriatic acid,* a substance which unites with ammonia, so as to prevent the heat driving it away, and a compound of the ammonia and the acid was obtained in the vessel. Liebig estimated that, if a pound of rain water contained one-fourth of a grain of ammonia, a field of 26,910 square feet would receive annually upwards of 80 lbs. of it, or 65 lbs. of nitrogen;† so that a statute acre would each year receive, in the rain which falls upon its surface, about 129 lbs. of ammonia, containing 106 lbs. of nitrogen.‡

20. The other compound which the atmosphere contains is a gas called CARBONIC ACID, formed by the union of the black inflammable substance charcoal, or, as chemists term it, *carbon*, with oxygen.

21. When wood or peat is burned in a close vessel or in a heap covered over with sods, in such a manner that the air has not free access to it, as is occasionally done by farmers in preparing turf for manure, it does not consume as when burned in our fires, but there is left a considerable quantity of a black-coloured porous substance, lighter than the material employed, and which may be exposed to the most intense heat without undergoing any change, provided we exclude the air. This substance is insoluble in water, and consists chiefly of one of the simple elementary bodies termed *carbon*, combined with some earthy impurities. In the process of manufacturing gas for illumination, coal, which is a compound of carbon with several gases, is exposed to a strong heat in

* Muriatic acid is the liquid sold as spirits of salts. It is a solution in water of a pungent suffocating gas of a sour taste, formed by the union of hydrogen and chlorine. The solution is very sour, and, when brought into contact with ammonia, immediately unites with it, forming a white solid substance named chloride of ammonium, or sal-ammoniac. The ammonia coming off from manure-heaps may be detected by bringing near the manure a narrow slip of window glass, or a feather wet with spirits of salts, when the white solid compound will be produced on the glass.

† By weight, 100 lbs. of ammonia consist of 82½ lbs. of nitrogen and 17½ lbs. of hydrogen.

‡ A useful property of charcoal, and one which renders it most interesting to the farmer, is its remarkable power of absorbing gases and of giving them out again when moistened with water: thus, of ammonia, wood charcoal absorbs 90 times, and of oxygen 9 times, its own volume. The coke of the gas manufacturer usually contains from 75 to 95 per cent. of pure carbon.

an iron vessel, the volatile gases pass away, and in the vessel remains a black substanee, the carbon of the coal.

22. When a piece of wood, or common charcoal, is burned in a vessel of oxygen gas, or with free exposure to the air, as in an open fire, it almost entirely disappears, and merely a small quantity of ash is left. In both cases, the carbon which they contain enters into *chemical combination* with oxygen, and the result of this union is the gaseous compound *carbonic acid*, which I have mentioned is one of the ingredients of the atmosphere.

23. If we place in a bottle a few pieces of common limestone, and pour over them some spirits of salts (*muriatic acid*) or common vinegar, a bubbling up of the liquid will be produced by the escape of a gas from the stone; but if we repeat this experiment with pieces of limestone from the same quarry *after they have been burned in the kiln*, neither spirits of salts nor vinegar will produce any escape of gas. If, however, we take a small quantity of the same burned limestone, after it has remained some weeks exposed to the air, spread over your fields, and treat it in the same manner, it seems to have recovered its original qualities, and a copious evolution of gas takes place, which, when examined by the chemist, is found to be identical with the gas which is locked up in combination with lime in the limestone rock, and also with the gas produced when charcoal is burned in the air or in oxygen gas.*

* To procure CARBONIC ACID we proceed as described above. The gas however, being soluble in water, must not be collected over the trough; but, as it is considerably heavier than atmospheric air, we can readily fill bottles with it, by a process exactly the reverse of that described for collecting ammonia, thus, instead of directing the tube of the flask *upwards* to the bottom of an inverted receiver, we make it pass *downwards* to the bottom of a bottle standing in its usual position. The heavy gas settles down to the bottom of the receiver, and displaces the lighter atmospheric air which flows from the mouth of the bottle. We may discover that all common air has been expelled by bringing a lighted splinter of wood near the mouth of the bottle, when it will be extinguished. Carbonic acid consists of 6 parts of carbon and 16 parts of oxygen; and, though the former of these is an inflammable substance, and the latter a gas remarkable for its power of supporting combustion, when chemically combined in the above proportions, they produce a compound which immediately extinguishes flame. The teacher should fill several bottles with the gas, and illustrate its properties.

a. It possesses acid properties.—When the tube from which the gas is escaping is made to descend into a glass containing some of the blue

24. Carbonic acid gas constitutes but a small part of the atmosphere, 5,000 gallons of air containing only about two gallons of it; but it is produced in enormous quantities by various operations in nature: thus, it is formed by the burning of the coal consumed in our fires, the process of burning consisting merely in the union of the combustible matter of the vegetable substance, whether it be the remains of ancient forests as coal, or the wood which is at present growing on the earth, with the oxygen of the atmosphere, and its conversion into this invisible gas. In some volcanic countries it is also evolved from the earth. It is considerably heavier than common air, and consequently accumulates in caverns and deep wells; and, being incapable of supporting life, it has frequently occasioned the death of persons incautiously descending into them. Like nitrogen it is incapable of supporting flame, and this quality has been the means of warning workmen of its presence in suspected places: thus, if a candle burns brightly in a well or newly opened cave, it is safe to descend; but if the candle be extinguished, or even burn feebly, we should endeavour to remove the deleterious gas before we enter. The most effectual means of doing this is to pour into the well or cave a few gallons of a mixture of quick lime and water; the carbonic acid unites with the lime in the same manner as when it meets with it in the open field, and the poisonous gas is locked up in the same state in which it exists in the limestone mountain, and is rendered incapable of doing injury.

25. It has already been shown (23) that carbonic acid exists in limestone. In Ireland it forms a large portion of the rocks of that formation which occupy so much of the centre of the kingdom; and the "hard chalk" cliffs of Antrim, the red limestone of Strangford Lough, and the black of Dublin, contain nearly 44 per cent. of their weight of this gas. When limestone is heated in the limekiln, the carbonic acid gas is

liquid, procured by boiling the leaves of the red cabbage in water, the colour of the liquid is changed to a bright red.

b. It is heavier than air, and extinguishes flame.—A bottle filled with it may be inverted over a lighted taper, when the heavy gas will descend and put out the light.

c. The tube conducting the gas may be allowed to descend into a wine glass containing some lime water, when the water will immediately be rendered milky from the formation of a compound of the carbonic acid and lime (*carbonate of lime.*)

driven off, the rock loses nearly half its weight, and the escaping gas has frequently proved fatal to persons who have fallen asleep near the place where lime was being burned.

26. Carbonic acid gas is also given out in enormous quantities from the lungs of animals in breathing. The air which, in a single expiration, we expel from our lungs contains from $3\frac{1}{4}$ to 4 per cent of it, and it has been calculated that the air which, in the course of a day, is expired by a full-grown man, actively employed, will yield as much of this gas as would be produced by burning 13 oz. of charcoal in an open fire. It is also, like ammonia, evolved wherever animal or vegetable substances are undergoing decomposition (15); so that when farm-yard manure, or vegetable matters of any kind, are mixed with the soil of your cultivated fields, a gradual and continued supply of both ammonia and carbonic acid is produced. But though carbonic acid is thus from so many sources continually escaping into the atmosphere, we find as has been stated (24), that it constitutes but a small part of its bulk. I will have occasion, in a subsequent chapter, to explain how the accumulation of this gas, so injurious to animal life, is prevented, and its production made to contribute to the support of the crops which you cultivate.

27. The examination of the materials of which our cultivated plants are composed shows us that, when deprived of water, nearly 50 per cent. of their weight consists of carbon. But, as it has already been stated (21) that that substance is insoluble in water, it is evident that it cannot, in its ordinary form, be taken up by vegetables. It is necessary that it should in some way be rendered soluble. This Nature effects by combining it with oxygen to produce the gas which I have just been describing; for carbonic acid dissolves readily in water, the agreeable taste of spring water and several fermented liquors being due to its presence. It is not only soluble in water, but possesses, when in solution, the power of dissolving lime and several other bodies not capable of solution in pure water. We know that it is by the solvent action of this gas contained in the streams which trickle over rocks containing lime that that earth is dissolved, and communicates hardness to our springs.* When boiled, the

* If a current of carbonic acid be allowed to pass for some time through the milky liquid described in note *c*, page 31, it will gradually become clear, carbonate of lime being soluble in an excess of this gas.

carbonic acid is expelled, and the water being incapable of retaining the lime in solution, deposits it as a crust on the sides of the vessel, and becomes "soft." You will find that an acquaintance with the properties of this gas will assist us in explaining many interesting matters connected with the soil.

28. The atmosphere is the never-failing reservoir from which innumerable tribes of plants receive the carbon necessary for their support. From the same source, also, the countless tons of carbon which the ancient forests required for their growth were derived. These, by a wise provision of nature, now supply us in our beds of coal with valuable deposits of fuel, which, consumed in our fires, unite once more with the oxygen of the air, and thus, after a rest of many thousand years, the carbon again takes its place in the atmosphere, to serve as food for plants, to cover the surface of the earth with shady forests and waving grain, to give strength to the tree and perfume to the flower, and to produce food for the support of man and animals. How well calculated is such information as that which I am now endeavouring to communicate to excite our desire for knowledge—to enlarge our ideas of that wisdom by which such arrangements have been planned!

29. Besides the gases which I have described as composing the atmosphere, there are also diffused through it minute quantities of various gaseous compounds produced in the innumerable operations going on everywhere around us; but these form so trifling an amount of its vast volume, and so little affect its general qualities, that it is not necessary for our purpose to notice them.

CHAPTER II.

MATERIALS EXISTING IN WATER.

30. We have passed in review the substances which enter into the composition of the atmosphere, and which therefore are accessible to the growing plant: we will now consider what Water is capable of supplying for its nourishment.

Composition of Water.—This substance, which is met with in nature under three forms—in a hard solid form, as ice; in a fluid state; and in a gaseous form, as vapour or steam—was, like the air, imagined by the ancient philosophers to be a simple element. It seems difficult to be believed by those unacquainted with the wonderful things which chemistry is capable of demonstrating by experiment, that the pure, healthful, and refreshing liquid, which in every country in the world is such a necessary of existence, should be composed of an unwholesome gas, one of the most inflammable bodies in nature, united with that remarkable life-and-flame-supporting element, oxygen, which we described as being so important an ingredient of the air that we breathe.

31. If we cause water to boil, we produce *steam*, the bulk of which is 1,694 times greater than the water from which it is formed. If we pass the steam through an iron tube, such as a gun barrel, placed across a small furnace and kept at a red heat, we find that a peculiar gas issues from the tube, which we can collect over water, while at the same time its inner surface acquires a coating of rust. This gas is named Hydrogen, and is the inflammable element which, united with oxygen, forms water. In the experiment, the steam, in passing over the red-hot metal, is decomposed; one of its ingredients, as we have stated, issues from the pipe as a gas, while its other element, oxygen, unites with the metal, producing the covering of rust, which is what is termed an *oxide*, being a compound of oxygen and iron. Hydrogen gas forms one pound in every nine pounds of water, so that for

every nine parts by weight of water converted into steam and decomposed, *one* part of hydrogen escapes as gas, while *eight* parts of oxygen enter into combination with the iron of the tube.

32. Hydrogen gas, as has already been mentioned (14), unites with nitrogen to form ammonia, and constitutes three pounds in every 17 lbs. of that compound. It is, like oxygen, destitute of colour, taste, or smell. It has not been found in nature except in combination with some other body. It is most inflammable, though, strange to say, not capable of supporting combustion: thus, if we fill a bottle with this gas and introduce into it a lighted candle, the flame will be extinguished, but the gas itself, where it is in contact with the air *at the mouth of the bottle, will take fire and burn with a pale yellow flame*, so that the candle will be relighted as we withdraw it from the bottle.* Oxygen gas, it will be remembered, possesses properties exactly the reverse of those just described; it is, unlike hydrogen, a powerful supporter of combustion but cannot itself be inflamed.

33. Hydrogen gas is the lightest body in nature, a hundred cubic inches of it weighing only about 2½ grains, while the same quantity of air would weigh 30 grains; therefore

* HYDROGEN GAS may be conveniently prepared by placing some cuttings of the metal zinc, or even a few iron nails in a bottle, furnished with a tube as before described, and pouring upon them some oil of vitriol diluted with three or four times its bulk of water; the water is decomposed, and hydrogen gas separates from it, escaping through the tube, and may be collected in a vessel over water, or in a bladder provided with a stop-cock. It may even be prepared, when no proper apparatus can be procured, by placing the materials described in a common ale glass, and covering the glass with the hand or a piece of moistened card paper to detain the gas. In collecting the gas over the water-trough, so as to prevent its being mixed with the common air which the bottle contains, fill a receiver twice the size of the gas bottle, and allow the impure gas to escape before collecting for experiment. *Ex.*—Place in a half-pint bottle about half an oz. of cuttings of zinc, half fill the bottle with water, and pour in vitriol until the gas comes off briskly, then close the bottle with a sound cork through which a gas-jet or a bit of the tube of a clay pipe has been inserted, and allow the action to go on for a few minutes to ensure the escape of the common air contained in the bottle; apply a light to the jet, and the gas will inflame and continue to burn with a pale yellow flame. Hold over the flame a saucer, and the burning hydrogen given off from the decomposed water will seize upon oxygen from the air, water will be reproduced, and the saucer will be covered with moisture.

when a balloon is filled with this gas it rises up through the atmosphere in the same way that a bubble of air ascends to the surface of water. Formerly it was generally employed for filling balloons, but coal gas, which is cheaper, is at present preferred for that purpose. Coal-gas, which is now so extensively employed for illuminating our cities, is one of those extraordinary products for which we are indebted to science. It is a compound of hydrogen and carbon, and in preparing it by the distillation of coal in large iron vessels, a small quantity of nitrogen contained in the coal is also driven off, which combines with a portion of the hydrogen to form ammonia. In the manufacture of gas the ammonia is removed by passing the impure gas through water, and this "gas-water," as has already been mentioned, is employed as a manure.

34. The chemist can by various processes cause hydrogen and oxygen to unite so as to form water; thus, if when hydrogen gas is escaping from a jet like that used for burning coal-gas, we set fire to it, and hold over the flame a common saucer, soot will not be deposited as when coal-gas is burned, but the saucer will be covered with drops of water. In burning, hydrogen unites with the oxygen of the atmosphere, and water is produced. Water formed in an experiment in this way is chemically pure, but in this pure state it is never met with in nature. It is in fact essential for the purposes which it is designed to serve that it should invariably contain other substances, One of its properties is its power of dissolving gases; some it absorbs in large, and others in only small proportions. Thus, while the mixture of coal-gas and ammonia of the gas-works is passed through it, the former escapes scarcely diminished, while the latter is retained. This property of water exercises an important influence upon its effects on vegetation. We invariably discover in rain and snow-water the constituents of the air, carbonic acid, oxygen, nitrogen, and ammonia. But spring and river-water, besides containing the above gases, are also contaminated with certain matters derived from the soil. If we place a few drops of spring-water on a slip of glass, and boil to dryness over a lamp or candle, the water is converted into steam, while the solid matters which were dissolved in it remain behind, in the form of a white or brown crust. It is by a similar process that the chemist procures *pure* water. He boils a quantity of spring-water to dryness in a glass or

iron vessel, and allows the steam to pass through pipes kept constantly cold, by which means the steam again assumes its fluid form, as we observe when a cold plate is placed opposite the steam issuing from a tea-kettle, the impurities of the water remain behind in the boiler. The same operation of distillation is constantly going on in nature; at every temperature and in every country, from the ice-bound seas of the north to the tropics, it has been found that water slowly passes to the state of vapour. The water on the surface of the earth, in passing into steam, leaves behind it the matters which it held in solution in its liquid state, and when it descends again to the earth in rain it is almost pure.

35. The solid matters that we discover in spring-water are the same that are found in the rocks of the country, and when we recollect that it contains carbonic acid, it is easy to understand how lime, and other mineral substances not soluble in pure water, may be dissolved by it from the rocks over which it has passed in its course. Both the kind and quantity of mineral matters which are found in the springs and rivers of a country vary very much, and are found to depend upon the composition of the rocks or soils over which their waters flow. The water of rivers, as might be expected, contains less matter in solution than that of springs, which, penetrating slowly through the earth, dissolve and take up the ingredients of the beds of rocks or sand through which they pass. In limestone districts we find the springs containing a large amount of lime, while again where they issue from the granite rock they are found to contain a mere trace of that substance, and to be comparatively free from impurities.* Some waters also contain a considerable amount of vegetable matter; thus in the water of the river Lys in Belgium, I have found so much as 2·86 per cent. of organic matters in the gallon. The quantity of mineral matters dissolved in any water must evidently

	grs.
* Water of a stream near Rostrevor, County Down, an imperial gallon contained of solid matter	10
Water of a stream supplying a flax-pool at Moneyrea, Co. Down	10
—— of a well at Shannon Grove, Co. Down	11
—— of a pump do. do. do.	28
—— of a well at Stranmillis, near Belfast	60
—— do. Irish Street, Downpatrick, Co. Down	140
—— do. (St. Dillon's Well) do.	40
—— do. Whitehouse, near Belfast	14½
—— do. Belfast	127

exercise a considerable influence upon its use in various operations, and especially upon the animals which use it for drink. Boussingault, the celebrated agricultural chemist, has directed his attention to this subject, and has calculated that by the salts dissolved or held in solution in the water used as drink by his cattle, 2 cwt. of alkaline salts (13) were added to his dung heap every year.

36. Water, therefore, by its power of absorbing the gases of the air, and dissolving the mineral matter of the soil, affords a means by which these substances may be introduced into the interior of the plant, and we shall see that it is requisite that all the matters which the soil supplies should be dissolved in this useful fluid before they can contribute to promote vegetation.

37. As in the laboratory of the chemist water can be decomposed into its elements, so when it penetrates into the interior of the plant, it can undergo decomposition under the influence of those curious agencies which the living vegetable is capable of exercising upon matter, its hydrogen being employed in the production of various compounds. Water is regarded as the chief source of the hydrogen of plants; and when it is worked up in the vegetable structure, oxygen is separated in its gaseous form, and returned to the atmosphere.

38. The quantity of water which is annually deposited upon the earth in rain differs very much in different countries. Over the whole earth it is estimated at from 32 to 33 inches, but from various causes the proportion of moisture which some countries receive greatly exceeds this amount. Thus, in different parts of England (Dr. Prout), it varies from 22 inches, as at London, to 68 inches, at Keswick, whilst at St. Domingo it amounts to so much as 150 inches. The water of the ocean is constantly passing into vapour and forming clouds, which are conveyed by the winds to a considerable distance into the interior of a country. From the peculiar position of Ireland, with its west coast exposed to the currents which carry with them clouds charged with the moisture exhaled from the immense expanse of the Atlantic, and which from various causes, and especially from coming into contact with the cold mountain ranges that fringe our coasts, have their temperature so much reduced that they are condensed into rain, which is precipitated in frequent showers over the land, the moisture of the climate of this coun-

try has become proverbial, and exercises considerable influence upon its agricultural character. From the observations which have already been made, it appears, as might be expected, that the quantity of rain that annually falls in this country on the west and south-west coast, considerably exceeds that which has been observed at Dublin, Belfast, and several places on the eastern shores. It has been estimated that the total amount of rain which falls over the entire surface of the island would, if collected, cover it to the depth of 36 inches; and that, of this water, not more than 12 inches annually reach the sea. The number of days upon which rain falls in Ireland is greater than in England or on the continent; thus, it is stated that on an average we have only 150 days yearly on which no rain falls. The constant evaporation of so large an amount of water from the surface of the island must exercise an unfavourable influence upon its temperature; for, to convert water into steam, to make it evaporate, a certain amount of heat is consumed. When we dip our hands in water on a hot day, and wave them through the air, they are rendered cool by the loss of the heat required to convert the water into vapour. Upon the same principle, the surgeon directs the patient to cover an inflamed part with pieces of linen dipped in water, or in mixtures which evaporate with greater rapidity. It is in the same way that our undrained fields are rendered cold, and the harvests in several districts delayed by the excessive moisture of the soil; the rays of the sun which should ripen the crop being expended in converting the surface water into vapour.* The thermometer, or measurer of heat, employed by the chemist shows a difference of several degrees between the

* The difficulty of drying agricultural produce was noticed a good many years ago by the celebrated Arthur Young. Farmers, however, in England have but little idea how much farm-work is influenced by our humid and variable climate. As an instance of this, we find it stated in the *Farmer's Gazette*, that while on the east coast of Ireland, in the neighbourhood of Dublin, the dew has dried up so that the haymaker can commence his work in the morning at seven or eight o'clock, and keep the hay opened out without danger of injury from the evening's dew till six in the evening; on the west coast washed by the Atlantic ocean, in Kerry and Cork, he considers himself fortunate if he can commence work in the hay-making season at nine A.M. and is obliged to gather the hay at four in the afternoon to protect it from the heavy dews or "sea-fogs."

temperature of the soil in a field which has been thorough drained and one which is lying neglected beside it. The undrained soil, therefore, is correctly regarded as *cold* by the farmer, and an extensive system of drainage is among the most important means to be adopted for improving the productive powers of our fields, and for enabling them to enjoy some of the advantages which other countries derive from a warmer sun. The undrained bogs and sheets of water which, like Loughs Neagh, Corrib, and Allen, cover so much of the country, must exercise a most injurious influence upon its general temperature; thus, it is found that the mean temperature of the island is about $49\frac{1}{2}$ degrees of the thermometer, which is only $4\frac{1}{2}$ degrees above the temperature at which many seeds placed in the ground refuse to vegetate. We need not, therefore, be surprised that, in many undrained districts, especially in our northern counties, but a small return should be given by the soil, and that the harvest should be delayed far beyond the safe and proper season. An excess of moisture in our soils is, in fact, their chief agricultural defect, and fortunately it is in the power of our farmers to correct this evil. The thorough drain will remove the water which consumes the heat of the sun, and allow the air to pass into the interior of the soil, warming it and giving it that temperature which will cause the dormant seed to vegetate, and at the same time supply to the young plant the gases required to promote its growth.* Nor will the advantages to be derived from the drainage of the country be confined to the farmer; all classes will be benefited in the increased salubrity of the climate, and the removal of many causes of disease.

39. Water, therefore, we have seen, not only, like the air, supplies plants with gases essential to their growth, but also

* I am informed by Doctor Orr that forty years ago, in a townland about two miles east from the Castlereagh hills in Down, the harvests were twelve or fourteen days on an average earlier than in Castlereagh, where the farms are more elevated and exposed; but that now, by superior cultivation, draining, manuring, &c. the case is altered, and the crops arrive at maturity from six to eight days earlier than in the former locality.

It is stated that in Aberdeenshire, in consequence of extensive drainage during the last twenty years, the crops ripen ten or fourteen days sooner than they formerly did.—*Mr. Gray in Prize Essays of the Highland Society.*

serves as the means by which they procure certain mineral matters no less indispensable to their development. These matters are not to be discovered in the atmosphere or in rain water, but exist in the rocks of which the ground on which we tread is composed, and which, broken into fragments of various sizes, from the finest dust to the stone that turns the plough aside, and, mixed with the decaying remains of the weeds or crops that have grown upon them, constitute the arable soil of the farmer. It is the carrying out of certain plans to enable plants in the readiest manner to supply themselves with the materials for their support which are stored in the soil that gives employment to the industrious labourer, and that requires both PRACTICE and SCIENCE on the part of him who has the management of the work.

CHAPTER III.

MATERIALS EXISTING IN THE SOIL.

40. We have considered the nature of the materials which the living plant obtains from the air and water, the important gaseous elements with which the Creator has stored the immense expanse of the atmosphere, and which in every part of the world are accessible to the vegetable tribes. I trust that you have received such clear ideas of the properties of these gases that you will be prepared to understand some remarks which I purpose making on the part assigned to them in building up the structure of your crops. We will, however, in the first place, direct our attention to the ingredients which the earth in which plants are fixed—THE SOIL, as it is termed—supplies for their support.

41. Suppose a stack of hay or of corn in one of your fields should accidentally be consumed by fire, you would find upon examination that the greater portion of the stack had burned away, had vanished into the air, and that there remained merely a small quantity of ashes which had resisted the fire. If you were to take a ton weight of sea-weed, and, after drying it, set fire to it in the rude furnace or kelp-kiln which is used by the farmers along our coasts, you would find that the great bulk of it would vanish into the air, but that there would remain in the kiln about 100 lbs. of a grey ash in a solid mass, like the slag of the iron-smelter, which could be fused by heat, but not consumed.

42. When the ash left upon burning a stack of grain or a heap of sea-weed is examined by the chemist, he finds that it is not a simple substance like iron or charcoal, but is made up of nine or ten different substances, with the names and appearance of most of which you are probably familiar. You may remember that I stated (31) that iron when it unites with oxygen gas becomes coated with *rust*, which is a compound of that metal and oxygen, forming what chemists term "an oxide of iron." In the ashes of plants we discern several

compounds of the same gas with metals and other elementary bodies, some of which possess *alkaline* and others *acid* properties. These substances are usually termed the earthy or *inorganic* constituents of plants. They are named Potash, Soda, Lime, Magnesia, Oxide of Iron, Oxide of Manganese, Silica, Chlorine, Sulphuric Acid, Phosphoric Acid.

43. Potash forms the greater part of the well-known alkaline substance sold by the grocer as Salt of Tartar, and also of the *potashes* used by some bleachers in this country. It is a compound of oxygen with a curious inflammable metal, Potassium, which, when thrown upon water, decomposes it, and unites with one of its elements, oxygen, while the other element, hydrogen, is separated, and burns with a beautiful flame. The same decomposition and production of flame are witnessed even when the metal is placed on a plate of ice. By simple exposure to the air also, it loses its metallic brilliancy by uniting with oxygen. In all these cases the same compound, oxide of potassium or *potash*, is formed. Potash exists in considerable quantities in the ashes of land plants, especially in those of the common bracken,* and of the wormwood. It is obtained by washing the ashes with water; the potash, being soluble, is dissolved out, and when the water is boiled to dryness in an iron pot, it is obtained united with carbonic acid, forming what is termed *carbonate of potash*. It is in this way that the *potash* of commerce is prepared, and that substance, separated from various impurities, is termed *pearl ash*. Potash is also contained in considerable quantity in the ashes of several kinds of sea-weed: thus in the ashes of some sea-weed from the mouth of the Clyde, there was found so much as 22 per cent of that substance.† By dissolving carbonate of potash (*potash or pearl ash*) in water and boiling it with some quicklime, you can separate the carbonic acid from it, and obtain a solution, which, when decanted from the sediment that is formed (*carbonate of lime*) and boiled to dryness in a covered vessel, will yield *pure* or *caustic potash*.

44. Soda is a substance closely resembling potash in its characters. It is met with in the washing soda of the grocer, in the soda ash and barilla of the bleacher, in the

* The *pteris aquilina* of the botanist.

† By Dr. Gödechens, of Hamburg, in the laboratory of Professor Will at Giessen.

salt cake of the glass manufacturer, and in the well-known "baking soda." It is the chief constituent of the ashes of sea-weeds, is likewise found in the waters of several inland lakes, and it also occurs in some countries covering the surface of the land.

Soda, like potash, is not a simple body, but a compound of oxygen with SODIUM, a rare metal, which in its separate state is only to be found in the laboratory of the chemist.*

45. LIME or quicklime is so well known to the farmer that it is scarcely necessary to describe its characters. Like potash and soda, it is a compound of a metallic body with oxygen, being an oxide of a metal termed CALCIUM. It is not met with in nature in a caustic state, but, combined with carbonic acid, forming *carbonate of lime* (25) it is abundantly diffused, and is found in every county in Ireland with the exception of Wicklow, sometimes rising into great mountain masses; in other cases, as in the great central plain, forming a subsoil of limestone gravel. Carbonate of lime, when pure, as in statuary marble, has the following composition in the hundred parts:—

Lime	56
Carbonic acid .	44
	100

When the compound is heated in the kiln, the carbonic acid assumes its original form of gas, and escapes, the stone losing 44 per cent. of its weight, and becoming caustic. A piece of limestone, you are aware, will not dissolve in pure water, but after burning it becomes slightly soluble, and dissolves in about 750 times its weight of water.

46. Lime is also found in Ireland, and in many parts of the world, combined with sulphuric acid (oil of vitriol) and water. The compound is known as *sulphate of lime*, *gypsum*, and *plaster of Paris*, and is raised for agricultural purposes at Carrickmacross, in Monaghan. It also occurs crystallized along the shore at Killroot, near Carrickfergus, in Antrim. In England it is found in great abundance, in several counties, in a compact state, and presenting various shades of colour. It is so soft that it can be scratched easily with the nail. The crystallized variety found near Carrick-

* Common potash when exposed to the air attracts moisture and becomes liquid (*deliquesces*) while the common soda of the shops (*carbonate of soda*) crumbles down to a white powder (*effloresces*).

fergus readily splits into thin layers, which are as transparent as glass. Gypsum is slightly soluble in water: 500 parts of cold water dissolving one part of it. When burned, it parts with the water combined with it, and can be readily reduced to a fine powder. In this dry state it exhibits a remarkable character, which has rendered it of great value in the arts, for when mixed with water, to the consistence of a paste, it hardens into a compact mass. Unburned gypsum usually contains about 21 per cent of water.

47. MAGNESIA is also a familiar substance. It is the calcined magnesia of the apothecary—and like the bodies just described, is a compound of oxygen with a metal, being an *oxide of magnesium.* It exists abundantly in the waters of the ocean, and in various parts of the world is found in combination with carbonic acid forming rocks which also contain lime, and are termed *magnesian* limestones. These rocks occupy a considerable extent in England, but in Ireland appear in only a few situations. They may be observed at Cultra, in the neighbourhood of the pleasant little village of Holywood, county of Down. Carbonate of Magnesia when exposed to heat parts with its acid more readily than carbonate of lime. The caustic magnesia produced is not so soluble in water as quicklime: one part of it requiring 5,142 times its weight of water for its solution. Rain water, however, charged with carbonic acid, is found to dissolve it more readily than lime.

48. OXIDE OF IRON.—The well-known metal, Iron at once the most abundant and the most important metallic substance found in nature, exists in every part of the world, combined with oxygen, and is also a constituent of almost all our rocks. It has already been explained that when a piece of iron is exposed to the air, it is gradually covered with a reddish brown rust, which is a compound of the metal with oxygen (42), taken from the air. This rust is termed by the chemist *peroxide* of iron, as there is another compound of iron which contains a smaller proportion of oxygen, and is named *protoxide*, or first oxide of iron.* Both of these oxides exist in the soils of this country. The first oxide has a great disposition to

	Iron.	Oxygen.
* The first, or protoxide of iron, consists in the 100 parts of	77.23	22.77
The second, or peroxide of iron, of	69.34	30.66

unite with more oxygen, and the change which the farmer frequently observes in the colour of the newly turned up mould from dark brown to an ochrey red, is produced by the protoxide of iron existing in the soil being converted, by exposure to the air, into the reddish brown peroxide. Protoxide of iron and its compounds are considered to be injurious to plants. You will, therefore, perceive how the various mechanical processes which tend to expose the particles of the soil to the influence of the oxygen of the atmosphere, may not only improve their texture, but produce important *chemical* changes in the ingredients which they contain.

49. Oxide of Manganese. Manganese is a metal which, in many respects, resembles iron. It unites with oxygen in several proportions, and a small amount of some of its compounds is discovered in the ashes of plants.

50. Silica is the earthy substance which constitutes the bulk of flint. Hence, it is frequently termed "earth of flints." It also forms a large part of sandstone, sand, and of the greater number of rocks with which we are acquainted. Rock crystal—beautiful specimens of which are found in the granite of Mourne—is almost pure Silica, and the white sand produced by the *wethering* of Muckish, and other mountains in Donegal, also contains it nearly free from foreign ingredients. Pure Silica is a snow-white tasteless powder. It is insoluble in water, and in all acids, except one named *Fluoric Acid.* When heated with potash or soda, it forms, according to the quantity employed, an insoluble transparent glass, or a compound that dissolves in water. In combining with these substances silica performs the part of an acid, and the compounds are termed *silicates;* when the alkali largely predominates the silicates dissolve readily in water, but when only a small amount is present, the compound is not dissolved by water, and is only slowly acted upon by strong acids; thus common window glass is an insoluble silicate, and the greater number of rocks consist chiefly of silica united with variable proportions of iron, lime, and other elements. The carbonic acid, and probably other acids, produced during the decay of vegetable matters slowly decompose the compounds of silica existing in the soil and in the straw of the manure heap, and when thus separated from the elements with which it was combined, silica becomes soluble in water, and capable of being taken up by the roots of plants.

51. CHLORINE is a suffocating, unwholesome gas, existing in *bleaching liquor*, and in common salt, united with the metal Sodium, which is found in soda.* It possesses the property of destroying vegetable colours and the odour of putrefaction, and is at present extensively used in bleaching and in the hospitals for fumigation.

52. SULPHURIC ACID is the important sour liquid, *oil of vitriol*, employed so extensively in various manufacturing processes. It is a compound of the well-known substance sulphur with oxygen. It is rarely to be found in a separate state in nature, but exists in a great many important compounds. The compounds formed by its union with alkalies, earths, and metals, are termed *sulphates;* (7) thus, in Epsom salts, it exists in combination with magnesia, forming *sulphate of magnesia;* in Glauber salts and salt cake, in combination with soda, forming *sulphate of soda;* and in gypsum, as already stated, (46) combined with lime, it forms *sulphate of lime.* The properties of sulphur are familiarly known; it is found in a separate form in Iceland and Sicily; and, combined with iron, in a mineral called *pyrites*, in Wicklow, in Ireland. It enters into the composition of several important vegetable compounds, and also forms one-twentieth part of the weight of hair and of the wool of the sheep.†

53. PHOSPHORIC ACID, or acid of bone earth. The name of this substance is probably not so familiar to you as those we have been considering. You must, however, have heard of phosphorus, the curious waxy-looking substance which gives out light in the dark, and when it is rubbed, takes fire. That substance was formerly but little known to the majority of people, and only to be found in small quantities in the shop of the chemist; but, at present, in lucifer matches and

* Common salt contains two-fifths of its weight of the metal sodium, combined with chlorine. The compound in the language of chemists is termed *chloride of sodium*, Chlorine also combines with potassium, the metal which exists in potash, forming a substance termed *chloride of potassium*, which resembles common salt in appearance, and is occasionally used in the manufacture of alum. It exists in the ashes of seaweeds, and is prepared in large quantities by the manufacturers of iodine.

† It has been calculated that in the wool grown in Great Britain and Ireland every year, five million pounds of sulphur are abstracted from the soil, to supply which to the plants upon which the sheep live, no less than 13,000 tons of gypsum would be required.

other useful contrivances for producing instantaneous light, it is everywhere to be found; and, in London alone, it is stated, that so much as 200,000 lbs. of it are annually consumed. When a piece of phosphorus is set on fire it unites with the oxygen of the air, and produces a white, solid, and strongly acid compound, which is *phosphoric acid.* This acid enters into the composition of all our cultivated plants, and united with lime produces a compound named phosphate of lime, which forms the chief part of bones, and also exists in considerable quantity in the milk of animals.*

54. Such is a plain account of the substances which the ashes of your crops invariably contain. In the infancy of agricultural science it was imagined that these earthy matters exercised no influence upon the plants of which they had formed a part — that they were only accidentally present. But as chemistry advanced and examinations of the ashes of plants became more numerous and accurate, it was ascertained, beyond all question, that these substances were most important—nay, indispensable to the existence of the vegetable kingdom, and that without their presence in the plant, even could it grow, it would be without value and incapable of serving us for food.

55. Within the last few years repeated examinations of both wild and cultivated plants have been made by chemists in this country and on the Continent, and it has been clearly shown, by careful experiment, that for a plant to come to perfection, or to form its seed, the soïl in which it is placed must contain the materials which we have just described, as entering into the composition of the incombustible ash of vegetables. But the discovery that every plant which springs up along the roadside, or is carefully tended in the farm, requires a certain amount of mineral matters for its development, is not the only useful intelligence which science has derived from this inquiry, or which it can afford to the farmer. It has, in addition, given to us a piece of information which is destined to exercise the greatest influence upon

* In the ashes of sea plants two elementary bodies are discovered which do not exist in the crops of the farmer. These are termed *iodine* and *bromine.* Iodine is a metallic looking substance, something like black lead in appearance; it is procured from kelp, and is at present very extensively employed in medicine. Bromine is a reddish brown liquid with a peculiar disagreeable pungent smell, which, when inhaled, excites violent irritation of the nostrils. It bleaches vegetable colours like chlorine.

the practice of agriculture in every part of the world. It has demonstrated that, not only does every plant require that the substances above described should be present in the soil for its use, but that the different families into which we are accustomed for convenience to divide our crops, are distinguished by a remarkable difference in the proportions in which these substances are found to exist in their incombustible remains, and that different plants, like wheat and clover, though growing upon soils of every variety of composition, *invariably select different proportions of particular kinds of matter for their nourishment*, some plants being found to contain in their ashes, and, consequently, to take up from the soil chiefly potash and soda, and others again silica or phosphorus, or sulphur. The value of this information will be fully illustrated in a subsequent chapter.

56. The proportions in which the materials that have just been described enter into the constitution of plants are subject to considerable variations. The following tables, however, constructed from the analyses of Boussingault will give you an idea of the composition of the organic portion of your ordinary crops, and also of the amount of matters derived from the soil, which that distinguished chemist found in the plants grown upon his farm in the east of France.

100 lbs. of the following plants in the fresh state usually contain—

	Dry Matter.	Water.
Wheat	85·5	14·5
Rye	83·4	16·6
Oats	79·2	20·8
Potatoes	24·1	75·9
Mangel Wurtzel	12·2	87·8
Turnips	7·5	92·5
Jerusalem Artichokes	20·8	79·2
Peas	91·4	8·6
Wheat Straw	74·0	26·0
Rye Straw	81·3	18·7
Oat Straw	71·3	28·7
Pea Straw	88·2	11·8
Clover Hay	79·0	21·0
Stems of the Jerusalem Artichoke	87·1	12.9

57. When all moisture has been expelled from the above substances, 100 lbs. of the dry matter has the following composition:—

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
Wheat	46·1	5·8	43·4	2·3	2·4
Rye	46·2	5·6	42·2	1·7	2·3
Oats	50·7	6·4	36·7	2·2	4·0
Potatoes . . .	44·0	5·8	44·7	1·5	4·0
Mangel Wurtzel . .	42·8	5·8	43·4	1·7	6·3
Turnips . . .	42·9	5·5	42·3	1·7	7·6
Jerusalem Artichokes .	43·3	5·8	43·3	1·6	6·0
Peas	46·5	6·2	40·0	4·2	3·1
Wheat Straw . .	48·4	5.3	38·9	0·4	7·0
Rye Straw . .	49·9	5·6	40·6	0·3	3·6
Oat Straw . . .	50·1	5·4	39·0	0·4	5·1
Pea Straw . .	45·8	5·0	35·6	2·3	11·3
Clover Hay . .	47.4	5·0	37·8	2·1	7·7
Stems of the Jerusalem Artichoke . .	45·7	5·4	45·7	0·4	2·8

CHAPTER IV.

SUBSTANCES INTO WHICH PLANTS CONVERT THE SIMPLE ELEMENTS UPON WHICH THEY LIVE.

58. We have for so far strictly confined our attention to the consideration of the store of materials which a bountiful Providence has placed in the air, the water, and the earth, for the nourishment of the vegetable tribes. We have seen that four elementary bodies,—Oxygen, Nitrogen, Hydrogen, and Carbon,—constitute the great bulk of every plant, and that the remaining portion is composed of a few mineral compounds with most of which you are familiar. The materials employed by nature are few in number, yet how varied are the forms they are made to assume in the plants and flowers that cover the earth!

59. You will now inquire, what is the nature of those substances into which plants convert the raw materials of their food, and which are discovered in the structure of the vegetable and in the various forms of nutritive matter stored in their seeds and roots? The question is natural, and leads to one of the most interesting parts of our subject.

The compounds which plants contain, produced by the union of the simple elements that I have described, are almost innumerable. The greater number of them, however, exist in exceedingly minute quantities: thus, the bitter substance Quinine, which is found in Peruvian Bark, and which at present is so extensively employed in medicine; the bitter principle which chemists extract from the bark of the root of the apple-tree; the curious element Iodine, which is obtained from the ash of sea-weeds, and the various colouring matters which almost all plants contain, form so small a proportion of the entire bulk of vegetables, that for the practical farmer in this country these considerations would be without any real advantage. But in every plant which it is the object of the farmer's care to bring to perfection, we find about half-a-dozen of compound bodies, distinguished by a remarkable similarity of composition, and upon the presence of which their value as food depends. To the consideration of these forms of matter we will therefore confine our attention, and endeavour to trace, so far as the light of science can clearly point out, the curious processes by which they are produced by the living plant from the gases of the atmosphere and the materials of the soil. Several of the substances to which I refer are procured from plants for food and other purposes, and are well known to every farmer.

60. If we proceed to examine any of our food-yielding plants, or the uncultivated tribes of the roadside or the mountain, we can, by a little care, make ourselves acquainted with their composition.

If we place in a Florence oil-flask some shavings of wood, and boil them successively in spirits of wine and water, continuing the boiling with each liquid so long as it dissolves anything, we will at last procure a white fibrous substance insoluble in water, and which has neither smell nor taste. This substance is termed *woody fibre*, and forms the bulk of the greater number of plants. The fibre of the Flax plant, which is so valuable for manufacturing purposes, and to procure which of good quality is the great object of the flax-growers of Ulster, consists of woody fibre united with a small portion of matters derived from the soil. It has been found that this woody matter of plants is chiefly composed of a peculiar substance to which the name of *cellular fibre* is usually given, and which is regarded as the earliest formed portion of their structure. In the development of the vegetable kingdom, cellular fibre is the chief building material employed. It can, by chemical means, be procured from all the parts of plants, and as prepared from the fibre of cotton it was found by a celebrated French chemist, who has particularly studied this subject, to possess the following composition:—

Carbon	44·35
Hydrogen	6·14
Oxygen	49·51
	100

It is curious to observe that in cellular fibre, no matter from what plant derived, whether from the spongy rush or the firm oak, the hydrogen and oxygen exist *in the same proportions in which these gases unite to form water;* that is, one part of hydrogen is combined with eight parts of oxygen.

61. When the wood of a tree is examined by a powerful microscope, it is observed to consist of layers, one of which is composed of the cellular fibre just described, while the others consist of an incrusting substance which differs from it in containing more carbon, and hydrogen in a larger amount, than would combine with the oxygen which it contains, to form water. Many interesting researches have lately been made respecting the composition of these layers, but the inquiry is of peculiar difficulty and must be regarded as only commenced.

62. When a piece of wood is placed in vitriol, it is blackened and assumes the appearance of charcoal; thus, you may have observed that a piece of cork placed in a phial containing vitriol gives a deep black colour to the entire liquid. The strong acid decomposes the woody matter and unites with its hydrogen and oxygen, the elements of water which it contains, while its carbon is set free.

63. The greater part of the heart-wood and bark of trees is composed of woody fibre. It constitutes 50 per cent of the weight of barley straw dried in the air, and about 80 per cent of the weight of the dried straw of the flax plant. In the root crops, however, its amount is but small, the white turnip in its fresh state containing only three per cent of it, but as the plants grow old its quantity increases, so as to render them stringy and unfit for the table.

64. Starch. Next to woody fibre, starch is one of the most common forms into which plants convert the materials derived from the air. It can be readily procured and its properties examined.

If we grate a potato upon a common grater placed over a basin, and allow a stream of water to fall upon the grater, so long as it flows through milky we perform a mechanical analysis of that root. At the bottom of the basin a white powder is gradually deposited from the water. This powder is the well-known substance Starch, which is met with in greater or less quantity in every vegetable, and which under different names—as *arrow root* when procured from the roots of a West Indian plant, *sago* when extracted from the pith of a species of palm, and *farina* when manufactured from potatoes,—is used for food in almost every country. No matter, however, from what plant or in what climate starch has been produced, the chemist recognises its composition to be the same, and is able at once to detect its presence by a property which it possesses of producing a beautiful purple colour when brought into contact with a solution of the metallic-looking substance iodine,* which I have described as an ingredient of the sea and of the plants which live in its waters. (*See note, p.* 48.) Like cellular tissue, starch contains no nitrogen, but consists solely of carbon, and of hydrogen and oxygen united in the proportions in which they exist in water. Starch, as the mode in which it is procured shows, is insoluble in cold water, but dissolves, as you are aware, in boiling water, producing a jelly-like liquid. By the influence of several chemical agents, and also by means of a peculiar substance generated in plants, starch can be made to undergo important changes, which, as they are of great interest in connexion with the growth of plants, it will be necessary briefly to consider.

65. When a portion of farina or any kind of starch is placed in a flask with water and boiled, a thick jelly is produced, which when dried has the appearance of glue, is, like the starch itself, insoluble in cold water, and is in the same way coloured blue by a solution of iodine. If we make an infusion of barley, and add to it the starch jelly, and keep them some time together, no change is produced; the starch remains undissolved; but if the grains of barley employed in making the steep have been allowed to vegetate in the field, or have been made to vegetate by art, by "malting" as it is termed, there is a most surprising difference in the effect produced. The starch is seen to grow gradually more liquid, and in the course of a few minutes its consistence entirely disappears, and it becomes as thin and transparent as water. If we evaporate to dryness the transparent solution, we do not obtain a jelly-like mass such as would result from evaporating a simple solution of starch, but a yellow powder which differs from it in being *readily soluble in cold water.* The solution of this powder is not rendered blue, but of a wine-red colour, by the addition of iodine, showing that the starch originally contained in the liquid has undergone some singular change, and in fact, that the elements which compose it are no longer united in the same form.

66. This yellow powder possesses the properties of a gum,

* A solution of iodine in spirits of wine is sold by the apothecary as *tincture of iodine.*

and is termed *Dextrin.* In the vegetating barley, therefore, there must exist some agent which is not to be found in the unmalted grain and which is capable of effecting this important transformation. It is a truly brilliant achievement for modern science to have succeeded in investigating this curious subject, and to have ascertained that the agent which produces the change is a peculiar substance named *Diastase*, rich in nitrogen, and which you shall presently see performs an important office in the first period of vegetable life.

But science, though it can trace and regulate the changes produced by this curious agent, is unable to form it from its elements, but can merely employ it as developed by nature in the vegetating grain. A method, however, has been discovered, which enables us to a certain extent to imitate its effects; and as the process is of very great interest and may yet become of practical importance to these countries, I will briefly describe it.

67. If we place in a porcelain dish over a lamp some water containing a few drops of vitriol, and when the water boils add gradually to it a small quantity of starch previously beaten into a paste with water, the starch, instead of becoming a jelly, as when boiled with pure water (65), is rendered liquid, and after a few minutes' boiling, a drop of the solution, taken out and touched with the solution of iodine, no longer displays the blue colour which is characteristic of starch, but a wine-red tinge, such as that exhibited in the solution of the gum produced by the action of malt. If we continue the boiling a few minutes longer, the iodine will produce no change in the liquid, and if we now take the dish from the lamp, and add to it some powdered chalk until the acid taste of the solution be destroyed, and allow the mixture to settle that the compound which the chalk and the acid forms (46) may subside, the clear liquid will be found perfectly sweet, and crystals of sugar may be procured from it by careful evaporation.

68. Starch also undergoes transformation from the action of other agents: thus, when it is heated to a temperature somewhat higher than that at which water boils, as is practised in the preparation of what is called *British gum*, it is converted into dextrin; some sugar is also produced in the operation, and even the simple exposure of starch jelly to the air for a long period has been found to produce the same changes.

69. GUM is another substance which exists in several plants in considerable quantities. You are familiar with it as exuded from the stems of the cherry, plum, and other trees, and also with a kind of it sold in this country under the name of gum arabic, and which is procured from a plant of the acacia family, a native of Africa. There are two varieties of gum procured from plants: one, *soluble in cold water* and becoming a jelly or mucilage, like gum arabic; and another, represented by the gum of the cherry-tree, *soluble in boiling* but *insoluble in cold water*. Both kinds of gum, like starch, dextrin, and cellular fibre, contain *carbon united with oxygen and hydrogen*, the gases existing in the proportions in which they form water.

70. MUCILAGE. There is another substance, termed *mucilage*, resembling gum in its composition and several of its properties, which is found in the root of the common mallow, in linseed, and other oily seeds. It does not, however, like gum, dissolve in boiling water, but merely swells out in bulk. Like starch, it can be converted into sugar by the action of vitriol.

71. SUGAR, the characters of which are so well known, exists in the juice of several plants in great abundance, so that its extraction is a valuable branch of industry. Among the plants familiar to us in this country, the beet-root affords the largest amount of sugar, and in France is extensively cultivated for its manufacture. It exists also in small quantity in the juice of the turnip and parsnip, and in ripe fruits, and its presence may be detected by the taste in the clover and young corn. There are several varieties of sugar, the principal of which are, *cane sugar*, extracted from the sugar-cane of our colonies, and *grape sugar*, which is met with in the dried raisin, in the apple and other fruits, and in honey. It is into grape sugar that starch and the other forms of vegetable matter are converted by the action of the chemical means that I have described.

72. There are also peculiar varieties of sugar found in manna, in liquorice, and in the juices of several plants, which differ slightly in composition and properties from those I have mentioned; but the two chief kinds, cane and grape sugar, contain oxygen and hydrogen united, and carbon nearly in the same proportion as in starch and gum.

73. ALBUMEN. By grating a potato as already described,

under a stream of water, we effect a separation of its parts; the starch contained in it is carried through the sieve and gradually deposited from the water, while in the sieve a fibrous matter is retained. If we boil the clear liquid from which the starch has fallen down, a froth or curdy matter forms on its surface, which, from its resemblance to the coagulated white of egg, scientifically termed *albumen*, has been named *vegetable albumen*. Though this substance exists in plants in much smaller quantities than those we have lately been considering, yet we find it invariably present in their juices. It performs an important part in contributing to the nourishment of animals, and is distinguished from starch, gum, and sugar, by containing nitrogen, which is an essential constituent of flesh (8), and also a small amount of sulphur and phosphorus. In all its leading chemical characters, it agrees with animal albumen.*

74. GLUTEN. If you place some wheat-flour in a muslin bag and knead it with your fingers under a stream of water, so long as the water is rendered milky, you will find upon opening the bag that the flour has diminished in bulk, and that there remains a grey, adhesive, elastic matter, which, like birdlime, can be drawn into threads. This substance which does not wash away is called *gluten*, and is found in considerable amount in all vegetables, and especially in those parts of our cultivated plants which we value for food. From the milky fluid which runs through the bag starch will subside, and by pouring off the clear liquid after the deposit has taken place, and boiling it, white flakes of albumen will separate. The gluten of wheat consists chiefly of a substance termed by Liebig *vegetable fibrine*, which, like albumen, approaches closely to the fibre of muscle in its composition. It contains about 15 per cent of nitrogen and a small amount of sulphur.

75. VEGETABLE CASEIN. When peas are bruised in a mortar and the pulp then mixed with a considerable proportion of water, and strained through a piece of muslin, a milky liquid, from which starch is gradually deposited, passes through the sieve. If, when the liquid has become clear, it be decanted and boiled, no coagulation takes place as when albumen is present,

* The characteristic smell of rotten eggs is produced by the sulphur contained in the albumen or *white* coming off united with hydrogen in the form of a gas named sulphuretted hydrogen. The black stain which stale eggs produce on silver spoons is also occasioned by this gas.

but its surface becomes covered with a pellicle or skin, resembling the scum which forms on the surface of boiling milk; or, if to the liquid we add a few drops of vinegar, a curd falls to the bottom resembling in appearance the curd of milk, and which analysis shows to be almost similar in composition. The substance which exhibits these characters is named *vegetable casein*, and sometimes *legumin*, from its being procured from leguminous plants, that is, those which have the seeds enclosed in a pod, and in which it takes the place that in wheat is occupied by gluten. Like gluten and albumen, it is rich in nitrogen, and also contains sulphur as an essential ingredient.*

76. DIASTASE. We have seen that when barley sprouts, it acquires certain properties which are not possessed by the unmalted grain. Chemists can procure from the part of the potato which is attached to the young shoot, and also from generating (or sprouting) barley and wheat, a peculiar principle which they have named *diastase*, and which cannot be procured from unmalted grain or from that portion of a potato distant from the shoot. This substance has not been completely investigated, but, like gluten, albumen, and vegetable casein, is rich in nitrogen, and is supposed to be produced by the transformation of some of these compounds. Its effects upon starch are most remarkable, the diastase contained in one pound of malted barley being sufficient to convert five pounds of starch into sugar.

77. FATTY MATTERS, OILS, AND VEGETABLE ACIDS.—In plants there are to be found, in addition to the substances already noticed, certain fatty matters and oils, and also a great number of acid principles, which, though forming usually but a minute portion of their substance, frequently exercise an

* The following is the composition of the bodies above described:—

	Albumen.		Fibrine.		Casein	
	Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Carbon . .	54·74	55·461	54·603	54·686	54·138	54.825
Hydrogen .	7·77	7·201	7.302	6·835	7·156	7 153
Nitrogen .	15·85	15·673	15.810	15.720	15·672	15·625
Oxygen . . } Sulphur &c. }	21·64	21·665	22·285	22·759	23·034	22·394
	100·00	100.000	100·000	100·000	100·000	100·000

important influence on their value for food. The fatty matters in plants are usually accumulated in the seeds, though found in greater or less quantity in all their parts. In the linseed and other seeds which contain them in large amount, the oil is separated for commercial purposes by the pressure of powerful machinery;—the mass or *cake* which is left is not entirely free from oil, and also contains other valuable substances of the seeds, and is at present in great demand for feeding cattle. Frequently, however, the fatty matters exist in so minute quantities, or are retained with so much force, in the cells of plants, that they cannot be abstracted by simple pressure; but the chemist can remove and ascertain their quantity by boiling the bruised seed in ether, in which they readily dissolve. The solution, when exposed to the air, allows the ether to evaporate while the oil remains behind.*

78. When the gluten procured by treating wheat flour as described (74) is boiled in ether, we procure from it a fatty oil, which is not very different in composition from the fat which lubricates the machinery of the human body. A hundred pounds of wheat yields about two pounds of this oil. The fatty matters resemble starch and sugar in containing no nitrogen, being formed from carbon, hydrogen, and oxygen only; they

* Composition of the cake of linseed, and of the cake of the seed of the *Camelina sativa*, or "Gold of Pleasure," according to the analyses of Professor Johnston—

	English Gold of Pleasure.	English Linseed Cake.	American Linseed Cake.
Water	9·95	10·05	10·07
Mucilage	35·08	39·10	36·25
Albumen and Gluten	25·50	22·14	22·26
Oil	12·42	11·93	12·38
Husk	10·16	9·53	12·69
Saline matter (Ash) & Sand	6·89	7·25	6·35
	100	100	100

The following is the produce in France, per acre, of oil and cake of the plants most familiar to the Irish farmer—

	Seed produced per acre. cwt. qr. lbs.	Total of oil per acre, in lbs. avoir.	Oil per cent.	Cake per cent
Winter Rape	16 2 18	641·6	33	62
Gold of Pleasure	17 1 16	545·8	27	72
Flax	15 1 25	385·0	22	69
Hemp	7 3 21	229·0	25	70
Summer Rape	11 3 17	412·5	30	65

are, however, distinguished from those compounds by containing a less amount of oxygen.*

Vegetable Acids. The sour or acid principles contained in plants are numerous; some of them contain merely carbon and oxygen, while others consist of these elements in union with hydrogen in various proportions. In the living plant these acids are united with various ingredients derived from the soil, and when the plant is burned they are decomposed, producing carbonic acid, and the alkaline and earthy substances with which they were combined are discovered in the ash in the form of carbonates. We have examples of vegetable acids in the acid of vinegar (acetic acid), which exists in the juice of several plants; in the acid of apples (malic acid) in the acid of the cuckoo sorrel (oxalic acid), in the acid of grapes (tartaric acid), and in the acid of lemons (citric acid). These compounds, however, are of so little practical importance to the ordinary farmer, that it would be out of place to describe their properties.

79. Such then, are the forms into which plants convert the crude materials supplied to them by Nature. The great mass of all vegetables, as well as of the nutritious substances formed within their structure, consists, as we have seen, of carbon, derived from the carbonic acid of the atmosphere. This element, which the air that surrounds the growing plant is at all times capable of conveying to it in unlimited quantity, simply

* The quantity of oil and fatty matter contained in our cultivated plants has not, until lately, received much attention from chemists. Professor Johnston, in his lectures, gives the following as the results of some analyses of the flour from seven samples of wheat grown by Mr. Burnett, of Glenarm, County of Antrim, at Gadgirth in Ayrshire. The results obtained show, that the proportion of oil, as of the other substances contained in our crops, is materially influenced by soil and cultivation:—

		Oil per cent.
1.	From the undressed soil	1·4
2.	Dressed with Guano and Wood Ash	1·9
3.	——— Artificial Guano and Wood Ash	2·2
4.	——— Sulphated Urine and Wood Ash	2·2
5.	——— Sulphate of Soda	2·0
6.	——— Common Salt	2·7
7.	——— Nitrate of Soda	2·3

But the proportion of oil in the flour is much less than in the entire grain: thus, while a sample of grain gave Professor Johnston, in the first flour, only 1½ per cent of oil, he obtained from the bran above 3 per cent.

by uniting with water, or with the gases hydrogen and oxygen which compose it, is capable of producing woody fibre, starch, sugar, and the various oils and acids. The same elements also, by uniting in different proportions with nitrogen, derived from the ammonia of the atmosphere, and with a small proportion of sulphur and phosphorus taken up from the mineral matters of the soil, form a class of compounds approaching closely in their composition to the substances of which the bodies of animals are composed. These compounds are designed for food—are, in fact, the ready-formed materials of blood and flesh. It is surely well calculated to excite admiration when we reflect how, out of half-a-dozen of elements, such a variety of important compounds is produced. If you take a piece of the muscle of an animal—a piece of mutton chop, for example—and examine it, you will find that it consists chiefly of a fibrous substance. If you pour water upon it, you can render it quite white—you will wash away the blood upon which its red colour depends. Upon examining it you will also find that a portion of *fat* is mixed up with it. If you dry the flesh and burn it, you will find that, like the plant, it consists of two parts—a part which disappears into the air, and an incombustible ash which remains. This ash, when examined by the chemist, is found to contain the very same substances that we have described as composing the incombustible part of plants. I have already stated that the gluten, the albumen, and casein of the vegetable world are almost identical with the fibre of muscle, and that the fatty matters which exist in the seeds of plants (78) contain the same elements, united in nearly the same proportions, as the fat with which the human body is supplied to facilitate the movements of our joints and muscles. Thus, in the interior of the plant, Nature prepares a store of materials, which, like the ready-formed wheels and screws that the watchmaker has merely to put in their proper places, in constructing or repairing a watch, are capable, when taken into the stomach, of being at once selected and applied to build up the frame and covering of the body. The soil of the field and the carbonic acid, the watery vapour, and the ammonia of the air, contain the elements of flesh and blood; but these elements must undergo certain changes before they can serve us for food. The office of plants is to effect these changes. They are the agents incessantly at work extracting from the atmosphere its gases, and from the earth its minerals, for our use. By the industry of the farmer, as I shall have occasion to show, the amount of the above nutritive compounds may be immensely increased, and, at the same time, the soil made to support a greater number of plants, and consequently to afford a larger amount of food for man.

CHAPTER V.

STRUCTURE OF PLANTS AND CHANGES WHICH ACCOMPANY THEIR GROWTH.

80. Having completed our survey of the raw materials with which nature has stored the soil and the air, to be employed by the crops of the farmer and the tribes of plants innumerable which cover the surface of the earth for the production of the compounds which render them so valuable to man for food and medicine, and which afford him materials for his dress and dwellings, our attention is naturally directed to the arrangements, the machinery by which these compounds are formed. With every seed that the farmer, depending upon the scriptural promise,* commits to the soil, a new machine, far more curious than the locomotive steam-engine, or the most refined mechanical contrivance of the factory, is set in motion. To produce this seed all the energies of the plant have been exerted, it is the last and finished work of vegetable life, and in its structure admirably adapted for its important office. We will therefore commence with its consideration.

81. Leaving it to the botanist to describe the different forms in which seeds are presented to us, and the numerous curious contrivances by which nature protects them from injury, and secures their dispersion over the earth, in some cases providing them with silky wings to float through the air, and in others enveloping them in dense flinty coverings or canoe-like cases, which enable them to glide uninjured over the waters of seas and rivers, we will briefly inquire into the changes which are observed to accompany the development of the young plant.

82. You know that when in a favourable season you place the seeds of any of your plants in the soil of the field, in the course of a few days they undergo the same changes that we observe when barley is being converted into the "malt" of the brewer. The seed softens and swells, and there are pushed out two portions of its inner substance, which gradually increase in size and extend themselves in opposite

* "While the earth remaineth, seed-time and harvest, and cold and heat, and summer and winter, and day and night, *shall not* cease."

directions. One of these is to become the root, and the other the stem of the future plant.

83. This is the beginning of the work and in the first stage the ingredients of the soil in which it is placed contribute nothing to its growth. In the seed itself there is laid up a supply of all the earthy matters which are for some time required. Daily, however, the young plant increases in size, its colour as it approaches the surface becomes of a greener hue, the root pierces deeper into the soil and minute hair-like fibres branch off from it, leaves covered on their surface with innumerable pores or mouths unfold themselves on the stem, and it now begins to condense within its structure the gases with which the air surrounds it, and to convert them into wood, starch, and the various compounds which we lately described. Next the flower comes, and following it the fruit and seed, and then in the commonly cultivated *annual** crops the work which the plant was produced to accomplish being finished, the wheels cease to go on, and neither sun nor soil can stimulate them to new motions. The mature seeds, if not gathered by the husbandman, are deposited in the earth or dispersed by the winds. The plant withers and dies, and the dead matter undergoes a series of changes by which it restores to the soil and the atmosphere the materials which, for a time, had been abstracted by the living vegetable and confined within its substance.†

84. As it will be required frequently to refer to the offices performed by the organs of plants, it will be necessary briefly to describe their structure.

Every farmer is familiar with the parts of which a tree consists, he knows that a *root* binds it firmly to the soil, that a *stem* covered with a *bark* rises up into the air, and that

* *Annual* plants are those which ripen and die in the course of one year. *Biennial* plants are those which, like the carrot, produce leaves the first year, and in the second ripen their seeds and die. *Perennial* plants are those which like trees live for a number of years.

† Seeds may be kept for a considerable time uninjured, but the different species vary very much in this respect; thus, wheat has germinated after 100 years (Pliny), and rye after 140 years (Home), while the seeds of coffee cannot be kept any time without risk. Every year the loss to the farmer from seeds unsound, from bad preservation and other causes, is enormous; and, when we take into account the impositions practised by unprincipled dealers, we may fairly assume, that on the average, more than one half of the seeds sown in this country are lost.

green *leaves* are hung around it upon numerous *branches* as if to seize the winds that pass over them.

85. The *stem.*—When the trunk of a tree which has been cut across by the carpenter, is examined, it is found to consist of a number of layers or rings embracing each other, and enclosing a central mass termed the *pith.* *The bark* forms the exterior portion of the stem, and is capable of being divided into several distinct layers, the outer of these layers which has been compared to the thin membrane (cuticle) that covers the human body, and which rises into a bladder when the skin is blistered, is termed *the epidermis.* In plants having hollow stems like the grasses, the epidermis is a part of great importance, and is found to contain a large amount of silica, (50) forming a glassy network which gives strength to their structure. In some plants there is so much siliceous matter deposited in the epidermis, that when rubbed together they produce sparks.

86. Within the layers which form the bark, we observe a series of rings composing the *wood,* the outer of these layers are soft and spongy, and are the latest formed portions of the stem. When the wood and inner layers of the bark are examined by a microscope they are observed to be composed of hollow tubes or vessels, which extend from the root to the branches, while the central spongy mass, the *pith*, consists chiefly of cellular fibre, (60) traversed by tubes which are arranged in a horizontal direction. In old forest-trees the pith is found to have entirely disappeared, and to be replaced by firm wood, and in many of our rapidly growing cultivated crops, as in the carrot and parsnip, it is torn up by the growth of the plant, leaving a hollow stem.

87. Though the stems of the greater number of trees possess the regularity of structure just described, yet many of our most familiar plants, as the grasses, exhibit an entirely different arrangement of parts. This difference of structure has led Botanists to divide our cultivated plants and forest-trees into two great classes, which they have designated by terms derived from the Greek language, one of those classes comprehends all those plants in which, as in that lately described, (85) the exterior layers of the woody matter of the stem are the latest formed,* the plant growing, as it were, by the

* The plants of this division are termed *exogenous,* from growing at the outside.

production of new layers external to those previously formed. In the other division they have arranged all those plants in which the growth takes place by the formation of new wood at the centre.* If you cut a stalk of young grass across you will have an opportunity of examining the structure of a plant of the second of these divisions. When it is viewed with the microscope, it appears to consist of a mass of cellular fibre, like the pith through which a number of tubes extend in a vertical direction.

88. For the sake of clearness, we will, however, confine our attention to the structure of the plants of the first division, which includes the greater number of forest-trees, and among our crops the potato, the turnip, the carrot, the bean, and the pea.

89. The *branches* are simply prolongations of the stem, and like it, consist of bark, pith, and woody matter.

90. The *leaves* exhibit almost every variety of form and beauty, and are of the greatest importance to the growth of plants. They consist internally of a fine network of branching vessels, which may be regarded as extensions of the vertical tubes of which the wood of the stem is composed, while the green exterior part is traversed by minute vessels which spread themselves on the surface of the leaf, and communicate with the vessels which run along the inner layers of the bark. The entire leaf is covered with a delicate membrane, which is an extension of the epidermis, and is perforated with minute holes or pores.† These little openings are especially numerous on the side of the leaf which is turned towards the ground.

91. The *root*, like the branches, is considered to be merely a continuation of the stem of the plant, and in its structure there is considerable resemblance; but as it descends into the earth its texture alters very much, it grows soft and spongy, and loses the green colour which is displayed by the parts above the surface. It sends off into the soil in all directions minute hairlike branches‡ which the microscope

* Such plants are termed *endogenous* from growing at the centre, and have but one lobe in the seed, while in the *exogenous* plants, as in the common bean, the seed is capable of being divided into two or more lobes; the grasses, among which botanists include wheat, barley, oats, rye, rice, &c., belong to the endogenous plants.

† *Stomates.* ‡ *Radicles.*

shows to consist of delicate tubes terminating in a porous sponge-like mass of cellular fibre. The pores discovered in the spongy extremities of the root-branches are so exceedingly minute, that it is impossible for solid matters, no matter how finely divided, to pass through them. It is, however, by these pores that the living plant is supplied with some of the materials most essential to its existence, and the power which the spongy extremities of the root possess of sucking in the moisture of the soil and the matters *dissolved* in it, and of conveying it to every part of its structure, is one of the most remarkable phenomena which the study of plants presents. You will now perceive the immense importance of a proper supply of water to vegetable life; dissolved in that useful liquid, the gases, carbonic acid, oxygen, and ammonia, as well as the earthy and saline matters of the soil, can readily be taken up by the plant and employed in its development.

92. Growth of Plants. After this survey of the parts which constitute the machinery of the plant, let us consider the nature of the changes by which it can within its structure convert the simple materials which it imbibes into the various interesting compounds lately described.

Development of the seed. As has already been stated (81), a seed when placed in the ground is observed in the course of a short time to undergo a remarkable alteration, like what is produced by malting barley. It swells up and acquires a sweet taste, and from its interior two portions extend themselves, which gradually increase in size and become the root and stem of the future plant.

93. In the first stage of its growth the young plant lives at the expense of the matters stored within the seed; water alone of the materials existing in the atmosphere and the soil contributing to its development; and instead of accumulating food from the air which penetrates into the soil, a portion of the carbon of the seed enters into combination with the oxygen of the atmosphere and is given off as carbonic acid. In the seed there is laid up a store of starch and gluten, but it will be recollected, that these compounds are insoluble in water (64, 74) and could not therefore enter into the vessels of the young plant: but under the influence of a certain temperature and moisture the gluten undergoes decomposition, and the curious substance *diastase*, (76) which in the hands of the brewer converts the insoluble starch of

the grain into the sugar of the wort, is produced. By means of this substance, which is discovered just at the point where the vessels extend from the seed to the sprout, the starch is dissolved, and, accompanied by the transformed gluten, made to contribute under the form of dextrin and sugar to the production of cellular fibre, of which the earliest formed parts of the young vegetable are composed.

94. For the healthy *germination* of the seed, as the first stage of vegetable growth is usually termed, there are certain essential conditions.

Moisture. Water is necessary in all the curious chemical changes by which the transformations lately described are effected. It is well known to the farmer that by steeping hard seeds in water for some time previous to sowing he will facilitate their growth. A perfectly dry seed will remain for years without exhibiting any sign of life, but if placed in a damp situation its inactivity disappears and it begins to germinate. An excess of water in the soil is, however, injurious to healthy vegetation, though some seeds sprout and flourish in situations where most of our cultivated grains would rot or produce an inferior crop.

95. *Air.* Without a proper supply of air no seed can germinate. When a piece of charcoal is burned in a vessel of oxygen gas, it is found that the bulk of the gas in the vessel is not diminished, but that its properties have been changed, *a quantity of carbonic acid gas is formed equal in volume to the oxygen which has disappeared.* A precisely similar change is effected by causing seeds to germinate in a receiver containing common air or pure oxygen. In both cases, oxygen gas disappears, and nearly an equal bulk of carbonic acid is produced at the expense of the carbonaceous matters (starch, &c.) of the seed.* Buried too deep in the soil where the oxygen of the atmosphere cannot reach them, seeds remain for centuries unchanged.

96. *Heat.* A proper temperature is no less necessary for the development of the seed than air and moisture. Below the temperature at which water freezes, germination does not take place.

In Europe and North America, the corn crops germinate at temperatures from 43° to 48° (Boussingault), and merely

* Some acetic acid (78) is also produced in germination; thus, germinating seeds placed upon blue test paper are found to colour it red.

live through the cold of winter without making progress, until the warm sun of spring gives a genial heat to the soil. When seeds are too deeply covered, not only is the free access of air prevented, but they are not sufficiently warmed by the sun. In undrained soils the seed immersed in stagnant water does not receive a proper supply of air and that increase of temperature which we have seen facilitates the transformation of starch into grape sugar and other compounds (68) is prevented, so that the plant which springs up is insufficiently nourished and seldom comes to full perfection. You will now be enabled to understand how in the thorough-drained field not only *earlier* but *more luxuriant* crops may be produced, and that by carefully pulverising the soil so as to allow the air to pass freely through it, we will materially hasten vegetation.

97. But, though it is injurious to bury seeds too deep in the soil, it will not do to leave them uncovered on its surface—not only does a light covering of porous earth protect them from sudden changes of temperature which might destroy them, but it prevents the action of light, which is found to interfere with those chemical changes by which oxygen gas is absorbed and a portion of the carbon of the seed converted into carbonic acid (95).

98. *Growth of the plant.*—Let us suppose that all the conditions required for the germination of the seed have been present, and that the machinery of the young plant thus set in motion has produced a root, furnished with its spongelike fibres stretching out into the surrounding soil, that a stem rises up into the air, and that waving leaves, agitated by every breeze, are hung around it with their pores or mouths prepared for the reception of food, and that it is capable of deriving the materials for its increase from all the sources described. How are these materials made to contribute to its development?

99. No sooner is the first true leaf of the young plant produced, than the mode of its growth undergoes a complete change, and a new circle of chemical operations begins. It no longer requires the matters contained in the seed, but seeks its nourishment in the soil in which it is placed and in the air that surrounds it. At this period the curious principle diastase is found to have disappeared, its assistance being no more wanted.

100. The little openings or pores, by which the membrane that covers the leaves is perforated, and the spongy extremities of the rootlets are the channels through which, in the form of carbonic acid, ammonia, and water, the growing plant is supplied with the carbon, nitrogen, hydrogen, and oxygen, which compose the bulk of its structure, and in the water sucked up from the soil it also receives the saline and earthly substances that we discover in its ashes (42). When our cultivated crops, at this stage of their growth, find in the soil an abundant supply of the peculiar matters which they require, they rapidly increase in size, and produce more numerous leaves and rootlets, and are thus enabled to appropriate more of the food which the air affords, but when these matters are not present in sufficient quantity in the soil, or are locked up in an insoluble form, it is impossible for them to come to perfection.

101. The gaseous and inorganic matters which, dissolved in water, the roots pump up from the soil, are conveyed by means of the vertical tubes, which compose the *wood* of the stem (86), to the leaves, and being there diffused through the network of branching vessels that cover the surface of the leaf, the solution (the *sap*) experiences an important chemical change, and also loses a considerable amount of water by evaporation. Thus altered, the sap descends by the vessels which run along the under surface of the leaf to the *inner* bark, where it contributes to the development of the plant. The quantity of water which is separated from the leaves of a plant by evaporation, must powerfully influence its growth, for in proportion as it escapes into the air, more water will be sucked up by the roots from the soil, and thus new supplies of the dissolved gases and inorganic matters be conveyed to the leaves to be converted into food. When from a continuance of dry weather the soil becomes incapable of supplying the water evaporated, the leaves are seen to shrivel up, and the growth of the plant is retarded. Dr. Hales calculated that the water converted into vapour by the leaves of a plant, was seventeen times more than that given off in perspiration from the human body. He found by experiment, that a sunflower lost one pound four ounces and a cabbage one pound three ounces a day by evaporation.

102. It is in the leaves that the sap undergoes those changes in its composition by which it becomes capable of

forming cellular fibre, and the various compounds that render plants "the sustenance and the banquet of animated nature!" The agent by which these alterations are effected is LIGHT.

103. When some fresh leaves of a healthy plant are placed in a tumbler filled with water, and inverted in a saucer also filled with water, and exposed to the sunshine, in a short time bubbles of air are observed to ascend to the bottom of the tumbler. This air when examined is found to possess the properties which belong to pure oxygen gas (7), and is believed to be produced by the decomposition of carbonic acid dissolved in the water (27), for when boiled water is employed in the experiment no oxygen is separated from the leaves of the plant. It is only, however, in the presence of light that the leaves of plants possess the power of decomposing carbonic acid (97). During the night season their roots continue to absorb the moisture from the soil and to evaporate it from their leaves, but the carbonic acid which they receive escapes without undergoing decomposition; instead of giving off oxygen they condense it in their structure, though numerous experiments prove that the amount of that gas which vegetables liberate during the day considerably exceeds that which they abstract from the air at night. The following beautiful experiment, tried by the illustrious Davy, will show you the effect which plants exercise upon the air that surrounds them. A piece of turf four inches square, clothed with grass, was placed in a porcelain dish which swam on the surface of a larger basin containing water in which carbonic acid was dissolved; over the dish containing the grass a glass vessel of the capacity of 230 cubic inches was inverted, so as to cut off all communication with the external air. The apparatus was exposed in an open place and so arranged that fresh water containing carbonic acid could be supplied occasionally to the water in the larger dish. After eight days it was found that the air in the glass vessel had increased by at least 30 cubic inches of gas which, when examined, was found to contain four per cent more oxygen than the air of the atmosphere.

105. It will be recollected that it was stated that the poisonous gas, carbonic acid, is from innumerable sources continually escaping into the atmosphere (26). The air that we *exhale* from our lungs contains a quantity of that gas, which, if existing in the same proportion in the air that we

inhale, would soon prove fatal to animal life. We know also, that by the combustion of the fuel in our cities, and during the decay of animal and vegetable matters, enormous quantities of carbonic acid are produced at the expense of the life-supporting oxygen. Yet the atmosphere maintains its composition unchanged (26), and analysis has proved that the wonderful mixture of gases that we draw into our lungs does not contain less oxygen or more carbonic acid than that which was inhaled by our ancestors many thousand years ago.

106. The experiments above described will at once suggest to you the means by which nature prevents an undue accumulation of carbonic acid in the atmosphere. By a beautiful arrangement the existence of the vegetable tribes has been made to depend upon the decomposition of that gas, *noxious to man but essential to their growth*, and every green leaf which plants hang out into the air is provided with an apparatus by which it is decomposed, and an equal bulk (103) of pure oxygen liberated to serve for the respiration of animals.

107. The diffused light of day is sufficient to enable plants to decompose carbonic acid and appropriate the carbon which it contains, but in the bright sunshine their growth proceeds with greater vigour, and the more plants are exposed to the sun the richer are they found to become in all those compounds in which that element abounds. It is only in the presence of the light that the leaf acquires its beautiful green colour, or forms woody fibre (61). In the deep mine and dark cellar, plants grow, but exhibit a sickly *blanched* appearance, and produce compounds of a different kind from those which we discover in them in their healthy condition.*

From what has been stated respecting the composition of starch, cellular fibre, and the other compounds of which the bulk of our crops consists, you can readily understand how by the decomposition of the carbonic acid and water which the sap contains, all the materials which their formation requires may be procured by the growing plant. The changes which the curious principle diastase is capable of effecting in the hands of the chemist, enables us to conceive how in one part

* Thus, in the blanched shoots of the potato a poisonous principle called *solanin*, is discovered which, when the plant becomes green by exposure to the light, disappears.

of the plant the same elements may exist in the form of a sweet and soluble sugar, and in another of a tasteless and insoluble starch. The changes by which albumen, casein, and the various compounds containing nitrogen, may be produced from the food which the plant receives, are not so easily understood, and their explanation would require details which, however interesting to the scientific agriculturalist, would be unsuitable in an elementary work. In another place I shall have occasion to allude to the influence which it has been found that an artificial supply of substances, rich in nitrogen, exercises on the production of these valuable compounds by the crops that you cultivate.

PART II.

CHAPTER VI.

THE SOIL—ITS FORMATION AND COMPOSITION.

108. We have for so far been occupied with the consideration of the nature of the raw materials which exist in the air and the earth for the development of the vegetable tribes, and of the peculiar forms so important to man which they are made to assume. It will be interesting and useful, now that we have finished this inquiry, to direct our attention to the soil, that great storehouse, from which plants procure the earths, the alkalies, and the metallic compounds which are invariably found to enter into their structure, forming their skeleton and giving them strength and firmness.

109. By the term *soil* is understood that layer of earth which the farmer ploughs and cultivates, and which gives support to his crops. Its colour and appearance vary very much. It occurs as the rich black mould of the garden, the turfy soil of the bog, the heavy red clay, or light-coloured calcareous covering. Its depth also varies from a few inches, as where it covers the clay-slate rocks of Down and Monaghan, to many feet, as in the deep sandy and alluvial beds of earth which constitute the arable land in many parts of Ireland.

110. When we examine the soil of a cultivated field minutely, it is found to consist of various proportions of sand, gravel, and dust, mixed with decaying remains derived from the roots and leaves of plants that have grown upon it, and the bodies of worms and insects that have lived in it. When we penetrate below these we find a layer of earthy materials, broken pieces of rock, and hard clay, containing fewer traces of animal or vegetable matter. This is what is termed the *subsoil*, and beneath this everywhere at varying depths is to be found a solid floor, composed of that kind of rock which prevails in the district. In one place we will find it consisting of a blue or white limestone, in another, of the black basalt, and in other localities, of the red sandstone or grey slate. There was a time when no soil covered the hard rock, and

its naked surface exhibited no trace of vegetable life. But every one must have observed how the surface of the rocks of a country gradually crumbles into powder, which, of different degrees of fineness, accumulates in the sheltered hollows, or is washed down upon the plains.*

111. In nature everything is subject to that change of form which we designate decay. The period at which this takes place is different for different forms of matter, but the difference is merely one of time. The flinty rock, the hardest metal, the densest wood, gradually change their forms. The great agents in producing these changes are the gases which exist in the atmosphere, and which, dissolved in the water that falls from the clouds penetrate into the earth and rest upon the surface of our buildings and the face of the rocks in our fields. By far the most energetic of these gases is carbonic acid, which penetrates into the crevices with the rain, and enables it to dissolve the lime, magnesia, and other substances of which the rocks are composed; these are gradually washed out, the cohesion of the undissolved portions being destroyed, and are easily carried away by the storm and rains and deposited upon the fields.

112. The inferior orders of plants assist in producing these changes. They are pioneers of vegetation, employed by nature in preparing a store of materials for those plants required as food by man. Thus, no sooner does the rain

* The rapidity with which a rock crumbles to powder by the influence of the atmosphere depends upon its density and power of absorbing moisture. In relation to this subject, I may here give some interesting examinations of Irish rocks, made by Mr. Wilkinson, architect to the Poor Law Commission. According to his experiments,

The chalk of Antrim weighs, per cubic foot, 160 lbs. and absorbs 3 lbs. of water.
Shaly Calp weighs, per cubic foot, 160 lbs. and absorbs from 1 to 4 lbs. of water.
The average weight of Sandstone, per cubic foot, is 145 lbs. and it absorbs 1 to 5½ lbs. of water.
Some Sandstones absorb scarcely any water.
The average weight of Granite, per cubic foot, is 170 lbs.
The Granite, of Glenties in Donegall, absorbs 4 lbs. of water, and that of Newry and Kingstown, ¼ lb. per cubic foot.
The average weight of Basalt, per cubic foot, is 178 lbs. and it absorbs less than ¼ lb. of water, per cubic foot.
The average weight of Clay Roofing Slate, per cubic foot, is 177 lbs. it absorbs less than ¼ lb. of water.

and its gases destroy the smooth surface of the rock and produce hollows, then the seeds of lichens and mosses which are floating about in the air, adhere to it, grow and increase, appropriating its materials and then die, giving it a covering of organic matter.* By their decay also, carbonic acid is generated, which contributes to accelerate the decomposition of the rock, and thus a *soil* is gradually produced.

113. In countries like Egypt, in which the air is dry and rain is almost unknown, decay does not proceed with such rapid steps as under our moist and changeable atmosphere. The surfaces of monuments in Egypt remain scarcely touched by the passing wings of time, while with us, all the massive buildings erected by the piety or ambition of our forefathers have been swept over as by a whirlwind.

114. The rapidity with which rocks wear and crumble depends in a great degree upon their composition; while the cinders of lava slowly fall into powder, the decay of granite and clay-slate proceeds more rapidly, and sandstone and basalt are still more quickly reduced to dust.* Darwin, in his interesting narrative of the voyages of the "Adventure and Beagle," gives a sketch of the vegetation of some of the coral islands in the Pacific Ocean, which shows the manner in which these singular formations receive their covering of plants. "The cocoa-nut tree," he says, "at the first glance, seems to compose the whole wood; there are however six other kinds, one of these grows to a very large size, but from the extreme softness of its wood is useless; another sort affords excellent timber for ship-building. Besides the trees the number of plants is exceedingly limited, and consists of insignificant weeds. In my collection, which includes, I believe, nearly the perfect Flora, there are twenty species without reckoning a moss, lichen, and fungus. To this number two trees must be added, one of which was not in flower, and the other I only heard of. The other is a solitary tree of its kind in the whole group, and grows near the beach where without doubt the *one* seed was thrown up by the

* I have closely watched the progress of decay in some of our clay-slate rocks, and the powerful effects in their destruction produced by the influence of plants. One of those which I have most commonly observed is the wild sorrel, *Rumex acetosella*, the roots of which I have found forcing themselves for a great length beween the layers of the rock, and in their progress loosening and finally tearing them asunder. The inferior orders of animals also assist in the work.

waves. I do not include in the above list the sugar-cane, banana, some other vegetables, fruit-trees, and imported grasses. As these islands consist entirely of coral, and at one time probably existed as a mere water-washed reef, all the productions now living here must have been transported by the waves of the sea. In accordance to this the flora has quite the character of a refuge for the destitute: Professor Henslow informs us, that of twenty species nineteen belong to different genera, and these again to no less than sixteen orders!"

115. In the character and appearance of the soils and subsoils of every country there are certain striking differences which immediately attract attention. What we have just stated of the mode in which the layers of earth that compose our fields have been produced will at once account for this dissimilarity. It is evident that when the soil has been formed by the crumbling down of a granite rock, it must differ considerably in character from that which has been produced by the decay of slate or limestone. When we take a quantity of the soil of a field and expose it to heat in a spoon or any convenient vessel, we find that, like a plant, it blackens in colour, that as we continue the heat the black portion disappears, and there is left a quantity of fixed incombustible matter. The weight of this incombustible part differs in different soils, in some amounting to 98 per cent of the whole weight, in others forming a considerably smaller proportion. The part that burns and vanishes, usually termed the *organic* portion, consists of the four elementary substances—carbon, oxygen, hydrogen, and nitrogen—derived either from the vegetables and animals that have lived and died upon the soil, or that have been added to it in manure by the farmer, while the *incombustible* matter is composed of the mineral substances of the rocks, by the decay of which it had been produced. This mineral portion, no matter from what kind of rock derived, is invariably found to consist chiefly of three substances, *Silica*, *Lime*, and a peculiar earth which we have not yet described, termed *Alumina*.

116. Alumina. Like lime and magnesia, alumina is a compound of oxygen with a metal. It is a chief ingredient of alum, and also of slate and pipe-clay, and exists pure in the sapphire, ruby, and some other rare minerals. It may be procured by adding to a solution of the common alum of the

shops some carbonate of soda (44); a white insoluble gelatinous looking deposit is produced. When this substance, which is *alumina*, is collected on a cloth and dried, it becomes a fine white powder, which when mixed with water, forms a tenacious mass which can be moulded into shapes, and it is upon its presence that porcelain, tiles, and brick clays depend for their useful properties. It is never found in a separate state in the soil. The substance which is termed *clay* by the farmers is composed of alumina *chemically combined* with silica (50) and a small amount of oxide of iron; pure *porcelain clay*, such as is produced by the disintegration or decay of the granite of Mourne, usually consists of about 42 parts of alumina, and 58 of silica.

117. Though alumina is an invariable ingredient of soils, yet it is not regarded as *directly* contributing to the nourishment of plants. The incombustible part of the soil is therefore distinguished from the ash of the plant by the presence of this substance. Its presence in the soil communicates to it tenacity and the property of retaining moisture; and Liebig is of opinion that by possessing the power of absorbing ammonia from the atmosphere it contributes to fertility.

118. It has already been stated that the differences which exist in the qualities of the soils of a country depend in a great degree upon the nature of the rocks from which they are derived. It will, therefore, be useful to make you acquainted with the composition of the rocks from which the arable soil of this country is derived.

By examining a geological map of Ireland, that of Griffith for example, it will be found that different districts are distinguished by certain marks or colours according to the kind of rock of which they are composed. Looking at the shading (*blue*) which denotes the *limestone* formation, it will be perceived what an immense extent it occupies, extending east and west, from Dublin to Galway, a distance of 120 miles; and north and south measuring 150 miles, and seldom in its course rising more than 300 feet above the level of the sea. Next in importance, will be observed the *clay-slate* formation, which in the north occupies so much of the counties of Down, Louth, Monaghan, Longford, and Armagh, and in the south constitutes the prevailing rock of Wexford, Waterford, Cork, and Kerry. Marked by shades of a different kind, (*red*) and interposed between the limestone and the coast, will be traced the boundaries of the large portion of the island which the *granite* covers, rising on the coast in northern Down into the graceful tops of the Mourne mountains, and composing the chief mountain ranges in Louth and Armagh; still farther north forming the uncultivated uplands of Donegal; running again more than sixty miles south-west of Dublin, and on the far west coast of the bay of Galway, opposing a rocky barrier to the Atlantic. In the north, particularly in Antrim, we find several rocks *basalt*, *white-chalk limestone*, *green sand*, &c. of a different kind from those which I have just mentioned, and which give that portion of the island its peculiar character.

119. When we examine the composition of the various rocks which exist in this and in other countries, we find that they are composed of the same materials which analysis discovers in the soil. The study of the rocks of the country is therefore of interest to the farmer, and the character of its soils may in a general way be predicted from an examination of a map on which its prevailing rocks are represented. The crumbling of a trap rock we may infer will afford a rich loam, like what is found in many parts of Antrim, while the granite rocks, especially if much elevated or exposed, will yield a poor and unproductive soil. Frequently, however, the soil of a district differs exceedingly in composition from the rock upon which it rests, and consists of materials carried by floods of water or other causes from rocks at a considerable distance. The rich soils which gave the deltas of Egypt their ancient renown, have been derived from the mud carried down by the waters of the Nile, and the fields (polders) of the Dutch farmers, are formed from the earthy materials washed from the plains and mountains of Germany by the waters of the Rhine, and which the industry of that people, by means of dykes have preserved from the action of the sea. The Rhine, we are told, brings with it 400 tons of solid matter daily. In many districts in Ireland, the soil is composed of *transported* materials consisting of clay and rolled limestone, and some of these deposits are of a remarkably productive character. It would be impossible, without entering into such details as would be out of place in this work, to describe intelligibly all the varieties of rock which occur in Ireland. It will however serve to extend your knowledge of the composition of soils, to give a short

account of the leading formations. I shall commence with the consideration of the granitic rocks.

120. Granite, as we have seen, covers a large space in this country; it composes also nearly the whole of Scotland, north of the Grampians. It contains nearly all the ingredients which plants require, but some of them in exceedingly small quantity. It is composed of three minerals, *quartz*, *mica*, and *feldspar*; and occasionally in some of the mountains described as granite, a mineral named *hornblende*, takes the place of mica, which, as it possesses considerable difference of composition, must materially influence the character of the soil derived from this rock. Mica, feldspar, and hornblende possess the following composition in the hundred parts.

	Mica.	Feldspar.	Hornblende.
Silica	46·10	65·9	45·69
Alumina	31·60	17·8	12·18
Potash and Soda	8·39	16·3	trace.
Lime	——	trace.	13·83
Magnesia	——	do.	18·79
Oxide of Iron	8·65	do.	7·32
Oxide of Manganese	1·40	do.	0·22*

121. From the variety of composition which granite exhibits, the character of its soils may be expected to vary. Though in the North of Scotland and in the West of Ireland granite soils being usually elevated, are regarded as most unproductive, yet industry can render them capable of yielding food, for on the lofty summits of the Wicklow mountains, 1600 feet above the level of the sea, splendid crops of turnips and flax are produced. The deficient ingredients in granite are phosphoric acid and lime, and accordingly the farmers in Mourne and the agricultural improvers in other granite districts find that, by the application of lime, or of bones, which contain both lime and phosphoric acid, they can procure excellent crops of oats and wheat (*see manures*).

* These minerals may be distinguished by the following characters:—

Quartz or Silica occurs usually crystallized in granite. It will scratch glass; a knife will not scratch it, but produces a streak like that made by a lead pencil.

Mica is of various colours; it occurs of a yellow colour in the Dublin, and of a black in the Newry granite. It is met with in shining scales, which split into layers when heated in the flame of a candle, and are so soft that they can be cut with a knife.

Feldspar, the next ingredient of granite, forms a large portion of its

When hornblende is present, the agricultural capabilities of the soil will be of a higher character; in addition to the potash supplied in abundance by the decomposing feldspar, the soil will then contain a large amount of lime and magnesia.

122.—MICA SLATE. Resting upon the sides of the granite mountains and covering a considerable surface of the country, especially in Ulster, where it constitutes the greater part of Donegal, Derry, and Tyrone, we find this rock, which derives its name from mica (120) being its chief ingredient. It is also met with in the north-east of Antrim, in the glens between Cushendall and Ballycastle. It is not found in Munster, but in Connaught it is the prevailing rock, and in the west of Mayo extends from Broadhaven to the sound of Achill, and it also spreads over a considerable surface in Galway. It is met with in a few spots in Wicklow. This rock splits into slaty layers which usually exhibit some appearance of the shining particles of mica. Its composition varies very much, and the soils which rest upon it exhibit considerable variety of character. It decomposes very slowly, and in general affords but thin and poor soils, which, being

bulk. Its usual colour is pale white, but it occasionally occurs of a flesh-red. It consists of silica, potash, and alumina. The silica is united as an acid with potash, forming a *silicate of potash*, (50) and with alumina, forming a *silicate of alumina*. The last of these compounds is the porcelain clay which in England is of so much value. From its composition, feldspar in granite readily decays. The rain charged with carbonic acid unites with the potash, thus forming soluble carbonate of potash, which is dissolved, while the insoluble clay, the cohesion of the rock being destroyed, is carried along and deposited in the valleys, leaving behind on the hills merely a sterile sand and gravel. Feldspar can be scratched by quartz.

Hornblende, as it occasionally occurs in the granite of the County of Down, (syenitic granite), is of a dark green or black colour and usually crystallized. It does not, like mica, split into layers when heated.

A specimen of granite from Annalong, County Down, examined in my laboratory had the following composition:—

Silica	74·00
Peroxide of Iron	3·00
Alumina	12·20
Lime	0·22
Magnesia	0·45
Potash and Soda	9·33
Fluoric Acid and Water	0·50
	100·00

usually elevated, yield but indifferent crops. In sheltered positions, however, and when it comes into contact with limestone and other formations, it improves in character. In Scotland the mica slate formation is largely developed, but in England it occurs only in South Devon and in Anglesea. Several specimens of clays produced by the decomposition of the mica slate of Donegall, and deposited at Milford and other places on the northern coast, appear well adapted for the manufacture of draining-tiles.*

123.—Clay Slate. The rocks which receive this name are found overlying those last mentioned, and occasionally, where the mica slate is absent, rest directly upon the granite. These rocks are of a slaty character and of considerable thickness, and the upper layers, which are found to contain remains of shells and vegetables, are usually termed *upper* slate to distinguish them from those in which no "organic remains" have been discovered, and which are described as *lower* slate. *The lower slate* covers a great extent of the kingdom, resting upon the flanks of the Mourne range, and forming nearly the whole of Down and Louth, except a small portion north of Dundalk. In the south it forms parts of Wicklow, Tipperary, and Cork. In the south also, *the upper clay slate* extensively prevails in Cork and Kerry, but in Ulster and Connaught it is only to be met with in Galway and Mayo, and in small patches in Tyrone and Fermanagh.

124. The predominating ingredient in the clay-slate rocks is a compound of silica and alumina in the state in which they exist in porcelain clay (115). In addition to these they contain silica and oxide of iron with traces of lime, magnesia, and alkalies. They also frequently contain a mineral named *chlorite*,† which

* Analysis of a subsoil resting on decomposing mica slate at Ballymacool, County Donegal. 100 parts had the following composition:—

Water	1·60
Organic Matters	3·00
Sand and Earthy Matter	88·50
Peroxide of Iron	4·00
Alumina	1·60
Lime	no trace.
Magnesia	0·36
Phosphoric Acid	?
Alkalies	0·24
	99·10

† This mineral is very abundant in the clay-slate rocks of Down. Its name is derived from a Greek word, signifying *green*.

gives them a greenish colour. In some places they are exceedingly hard and not easily decomposed, but in other situations, as when close to the mica, they crumble down more readily. The soils produced by their decay exhibit considerable variety of agricultural character, and their fertility is considerably influenced by the presence of other rocks, and also by the position of the layers of rock upon which they rest. On the summits of the round hills which stud the Counties of Down and Monaghan, they are in general light and *greedy*, requiring large supplies of manures; but where the rock upon which they rest is but slightly inclined, they are of greater depth, and where traversed, as in several parts of the County of Down, by veins of carbonate of lime, of considerable fertility. In some of the slate districts in Ulster, heavy clay soils are found, which, when undrained are worked with difficulty, but by judicious management are capable of yielding large crops of wheat. In Scotland the rocks of this formation yield poor soils, and are in many places covered by bog and heath.

125. In those rugged hillocks or "knowes," which are to be found rising up through the cultivated fields in many of the northern counties, but which are rapidly disappearing before the pickaxe of the enterprising farmer, the clay slate may be observed in various states of decay, presenting different shades of colour, from the close, flinty, and unaltered grey rock to the brownish red friable slate, which is gradually crumbling down into powder. These varieties in the colour and texture of the rock, depend chiefly upon the changes which air and moisture produce upon the iron which it contains. In the unaltered rock, iron exists united with a minimum quantity of oxygen, in the state of protoxide, (48) but this compound gradually unites with more of the oxygen of the air, and the higher compound, the brownish red peroxide is formed, which as it is more bulky than that originally present, occupies a greater space and destroys the cohesion between the particles of the stone, and disposes it to crumble to pieces. Though clay slate in its unaltered state contains nearly all the elements required by plants from the soil, yet some of them exist in it in very small proportions, and it is found that during its decomposition, especially in elevated districts, its more soluble ingredients are washed out by the rains, so that the soils formed from it are remarkably deficient in lime and alkalies. Lime is indeed

their great want, and is applied with advantage and in large quantities by the farmers of the clay-slate districts.*

126. SANDSTONES.—If we examine some of the rugged mountain ranges that rise up in the great central plain of Ireland, in Longford, Roscommon, and farther south, in Cork, Tipperary, and Limerick, we find that they consist of a rock different in appearance from any of those which we have just considered, and which seems to be chiefly composed of grains of sand of various degrees of fineness, cemented together by an aluminous, calcareous, or siliceous paste, coloured red or yellow by peroxide of iron; such is the usual character of a *sandstone;* what has been termed the *old red sandstone* consists of a great number of beds, and is placed between the clay-slate and the limestone, the lower beds therefore partake of the character of the clay-slate, and have received the name of *grey wacke*, while the upper beds, or those immediately below the limestone, contain a considerable amount of lime.†

127. There are beds of sandstone which occupy a different position from those just described, being placed *over* the limestone. These, however, are of but small extent, being found in only a few of the northern counties. The soils produced by the decay of the sandstone formation may be described as highly productive, but as might be expected from the variety

* Composition of decomposed clay-slate from Ards, County of Down.

Silica	56·66
Alumina	19·58
Peroxide of Iron	15·41
Lime	1·16
Magnesia	2·36
Alkalies	0.49
Water	4·34
	100·00

† Sandstone in the neighbourhood of Belfast.

Silica	54·34
Peroxide of iron	3·90
Alumina	4·35
Carbonate of lime	30·00
Carbonate of Magnesia	2.49
Phosphate of iron	0.20
Alkalies	traces
Water and loss	4·72
	100·00

of composition which the beds present, they differ very much in value. They are in general loose and porous; and are especially adapted for the cultivation of fruit-trees and deep rooted plants; occasionally when the silica is in minute grains, and clay forms the cementing material, a moderately cohesive soil is produced. In England the open soils on the old sandstone in Hereford and the neighbouring counties are famous for their orchards, and in this country the best fruit-growing districts of Kilkenny and Limerick are situated on this formation. The *new* red sandstone may be observed in the valley of the Lagan and also at various points along the coast of Antrim, where it occasionally contains beds of Gypsum (46) and rock-salt.

128. LIMESTONE FORMATION.—The limestone formation covers but a small space in England and Scotland, but in Ireland as we have already stated, it is largely developed, occupying fully two thirds of the island, and being found in every county with the exception of Wicklow. By the geologist it has been recognised as consisting in this country of three distinct formations or beds. These are named from their position the upper, middle, and lower limestones. The *lower* limestone forms the prevailing rock of the central counties, and affords the fine black marbles of Carlow, Galway, and Kilkenny, as well as the red marbles of Armagh. The *middle* limestone, which has received the name of *Calp*, occurs in the neighbourhood of Dublin, and consists of a dark limestone, containing a large amount of clay, and not more than 68 per cent of carbonate of lime. The *upper* limestone is not found in the central flat country, but in the north is discovered in Sligo, Fermanagh, and Leitrim, and in the south in Tipperary, Carlow, and Kilkenny. If you look at the distribution of the limestone formation, as laid down in the geological map, you will perceive, as has already been stated, that it occupies the great central plain of the island, extending in a straight line from Dublin to the coast of Galway, on the shore of the Atlantic. Its level, however, is frequently disturbed by the protrusion of sandstone rocks, and branches of it may be observed extending a considerable way from the central mass in Donegal and other counties.

129. In connexion with the limestone formation we may notice a variety of limestone which is found in a few places in Ireland, and which, from containing a considerable amount of

magnesia, is termed *magnesian* limestone. In England these rocks are of great importance, and largely developed, but in this country they possess but little agricultural interest. Magnesian limestone is found at Cultra, near Holywood, in the County of Down, on the shore of Belfast Lough, and varies in colour from a light yellow to brown. It also occurs at Howth, near Dublin, and in three or four other places in Ireland.

130. Though, as we have seen, the limestone formation may be regarded as forming the floor upon which the soil in a very large portion of the island rests, yet it is found that in the central plain the soils, even where placed upon a bed of this formation, possess characters which render it evident that they cannot have been produced by the decay of limestone rocks. Thus, analysis discovers that they are signally deficient in lime, and experience shows that their productiveness is materially increased by its application. "In those localities where the clayey diluvial gravel is interposed between the surface and the rock, the soil is usually wet and clayey; so much so as to become impervious to water. Hence has arisen the tendency to the growth of bog moss (*Sphagnum Palustre*) and other aquatic plants, which have gradually produced the bogs that occur so abundantly among the Eskers or gravel hills of our central districts. In those parts of the great limestone district in which the gravel deposits have not extended, the soil is rich and is capable of producing any kind of agricultural crop; but in these fertile plains less exertion has been displayed than in other parts of the country where the soil is of inferior quality; but where, owing to the industry of the people, the quantity and quality of the crop per acre, is superior to that produced on the rich calcareous loams."—(*Griffiths.*)

131. Trap or volcanic rocks. The next group of rocks to which I would direct your attention, as affording soils by their decomposition, are those which cover a large portion of the northern part of the kingdom, and are known by the names of basalt, greenstone, and *whin-stone*. These rocks are usually considered to have been converted into their present state by the action of fire, to be in fact composed of matter ejected from volcanoes; occasionally we observe them forced up in narrow ledges between rocks of an entirely different character. These are usually termed *whin dykes.*

The chief development of these rocks is in the County of Antrim, where a flood of volcanic matter seems at one time to have been poured over the beds of chalk, converting it into what is, in the north of Ireland, termed "white limestone." The volcanic rocks of Antrim border the north-east coast of that county for many miles, forming the picturesque cliffs which give that portion of the country its peculiar character, assuming, in the Giant's Causeway, the form of angular pillars, and in the magnificent promontory of Fairhead rising in massive columns to a height of 636 feet above the level of the sea. Detached masses of greenstone may be observed protruding in many parts of the kingdom; thus, Croghan Hill, in the King's County, Carlingford mountain, in Louth, and Urrisberg, in Galway, are examples of this rock. The volcanic rocks are of but limited extent in England, but in Scotland they cover a considerable area. They contain a great variety of ingredients, are readily acted upon by the weather, and the soils which are produced by their decomposition present great variety both in colour and composition. In Ireland they are usually fertile, but their character is greatly influenced by position. When they are flat they favour the accumulation of water, and are often covered with peat and marsh, and in many cases the soils produced by their decay contain so much iron as to prove injurious to the growth of the farmers' crops. The iron of the decomposing particles of rock is washed down by the rain, and frequently accumulates in the subsoil, forming an ochrey layer or *pan*, which is sometimes so hard as to be with difficulty broken up. Upon soils in which this accumulation has taken place, the crops thrive well until the roots descend to the *pan*, when they gradually fail, the excess of iron acting as a poison to the plants. Greenstone is sometimes composed of feldspar and hornblende (see analyses), and in other cases, of the former and *augite*, a mineral which like hornblende is rich in lime, so that in this mixture we have most valuable ingredients for the nourishment of plants. Below are given analyses of some of these rocks, and also of a soil resting upon them.*

* The beds of ochre which of various colours are observed along our north-east coast and also in the interior of Antrim have been produced by the decay of volcanic rocks. The following is the composition of Basalt and also of a specimen of red ochre from the cuttings of the

132. WHITE LIMESTONE. The rocks known to the farmers in the north of Ireland by the name of *white limestone*, though of great agricultural value as a source of manure, do not to any great extent directly contribute to the production of soils. These rocks extend over the greater part of Antrim and over parts of Down and Derry, and are regarded by geologists as identical with the beds of chalk which are so extensively developed in England, and merely altered in hardness by the action of the volcanic rocks. Being, however, covered over with the immense mass of basalt upon which the soils in Antrim chiefly rest, the limestone is only occasionally visible. It may be traced from the neighbourhood of Moira in Down to the banks of Lough Foyle, and is observed making its appearance beneath the basalt at various points along the north-east coast. The white limestone belongs to what is termed *the chalk formation*, which consists of a group of calcareous rocks, and beds of sand, clay, and marl. Some of the beds of the group contain a large quantity of fossil shells and other "organic remains," and considerable attention has lately been directed, both in this country and in England, to the deposits of *green-sand* found immediately below the white limestone (*chalk*), by the discovery that these beds contained

Ballymena Railway and of a subsoil in the neighbourhood of Larne examined in my laboratory. The subsoil was taken from a field belonging to Dr. Kirkpatrick, on which the oat crop had several years failed after exhibiting a most promising appearance.

	Basalt.	Red ochre.
Silica	53·70	26·00
Alumina	25·41	26·93
Lime	4,55	trace.
Magnesia	1·37	73
Oxide of Iron	8·95	Peroxide 35·57
Sulphuret of Iron	traces.	
Water	4·30	10·33 in 100 parts.

Subsoil from near Larne, Co. Antrim.

Sand and Siliceous matter	58·00
Peroxide of iron	12·60
Alumina	12·00
Carbonate of lime	0·40
Magnesia	0·58
Sulphuric Acid and traces of Alkalies	0·20
Organic matters	10·05
Water	6·15
	99.98

a large amount of phosphate of lime, (53) the compound from which bones derive their chief fertilizing qualities, and might, therefore, be advantageously employed as manure.

133. In the variety of composition presented by the rocks upon which the soil rests, we have a striking instance of wise arrangement; did they consist of merely one kind of matter, it would be impossible that our cultivated plants could grow, for as you have seen, we are not acquainted with any of these plants that does not require more than one kind of matter for its food.* In every country, however, not only have we a great variety of rocks, but few of these are absolutely pure; limestone does not contain merely lime, nor the quartz rocks of Donegal merely silica. In these apparently pure rocks chemistry discovers minute quantities of other ingredients. The more complex the composition of any rock, the greater probability of the soils formed from it proving fertile. This is illustrated by the well known productiveness of those districts where several kinds of rock occur.

134. *Organic matter of the soil.* It has already been stated (115) that when a portion of soil is burned until all blackness has disappeared, it is found to have decreased in weight, and that the incombustible ash which remains consists of the saline and earthy *inorganic* matters which are contained in the rocks by the decay of which it was produced, while the part that consumes is composed of the remains of the vegetables that have grown upon it, or have been mixed with it by the farmer. In all cultivated soils in this country, we discover a considerable proportion of this *organic* matter, and in peaty soils it frequently amounts to 60 or 70 per cent. In tropical countries the decay of the vegetable matter proceeds rapidly, and all the carbon of dead plants is restored to the atmosphere in the form of carbonic acid, but in Ireland and other cold countries this change is not so perfect, and the remains of vegetables accumulate in the soil, and when moisture is present frequently undergo a peculiar kind of decomposition, by which they are converted into the substance termed *peat.*

* The teacher will observe, that I have said that all our cultivated plants require more than one kind of mineral food, but respecting the exact number of substances which are *essential* to their growth, we are not yet sufficiently informed to decide. The only plants which have yet been discovered to contain no inorganic matter, are the little mould plants, which form on the surface of solutions of sugar and other organic substances. (Mulder.)

It was formerly erroneously supposed, that upon the presence of the decaying vegetable matter which gives the dark colour to the soil of the meadow and garden, and of which peat is chiefly composed, that the power of a soil to grow plants depended. This substance you will find frequently mentioned in agricultural works under the names of *Humus* and "vegetable mould;" and some chemists suppose that by its decay certain acids, rich in carbon, are produced in the soil, which in some forms of combination are capable of being taken up by the growing plant, and employed for its nourishment. The researches of Liebig, however, and other eminent authorities, are entirely opposed to this opinion, and have demonstrated that for a soil to be capable of supporting any plant it is necessary that it should contain the inorganic matters that we discover in the ashes of that plant. From what has already been stated you will readily understand the explanation which is given of the beneficial effects which experience has taught the farmer are derived from decaying vegetable matters in the soil. By the gradual union of the carbon of the dead vegetable with the oxygen of the air, carbonic acid is produced and slowly evolved from every particle of organic matter to which the air has access, and thus a more abundant supply of that source of food to plants is provided. The carbonic acid as it is formed is taken up by the roots of plants, and thus the crop attains a greater development than when dependent upon the ordinary supply of that gas afforded by the atmosphere. "If," says Liebig, in his Letters on Chemistry, "we suppose all the conditions for the absorption of carbonic acid present, a young plant will increase in mass, in a limited time only, in proportion to its absorbing surface; but if we create in the soil a new source of carbonic acid by decaying vegetable substances, and the roots absorb at the same time three times as much carbonic acid from the soil as the leaves derive from the atmosphere, the plant will increase in weight fourfold. This fourfold increase extends to the leaves, buds, stalks, &c. and in the increased extent of surface the plant acquires an increased power of absorbing nourishment from the air."

135. What is termed the *physical* qualities of soils, that is, their tenacity, porosity, power of absorbing and retaining water, &c. materially influence both the labour required for their cultivation and their productiveness. The atmosphere

and water, you have seen, supply plants with some of the most essential ingredients of their food, it is therefore important that the soil in which they are fixed, should possess that texture best adapted to allow the air and rain freely to penetrate to their roots. It is not, however, sufficient that a soil be loose and open, it must, at the same time, possess that degree of consistence which will afford plants a firm support. So far as its physical qualities are concerned, "the most productive soil is that which is so constituted as to maintain such a degree of moisture in very dry and in very wet seasons, as only to give a healthy supply of it to the plants. Such a soil gives to plants the means of fixing their roots sufficiently deep to support them during the period of their growth, and allows them to ramify in every direction in search of nourishment, where they may easily abstract the elements of vegetable life without being injured by a redundant or a deficient supply of moisture, during any period of their growth."—(*Morton.*) Though the physical qualities of a soil, and the proportions of sand-clay and vegetable matter which it contains, its elevation above the sea, and its depth, have, as the experienced farmer knows, an important influence upon its fertility, yet "a soil," as the chemist Sprengel, the head of the Prussian agricultural school, says, "is often neither too heavy nor too light, neither too wet nor too dry, neither too cold nor too warm, neither too fine nor too coarse, lies neither too high nor too low, is situated in a propitious climate, is found to consist of a well-proportioned mixture of clayey and sandy particles, contains an average quantity of vegetable matter, and has the benefit of a warm aspect and favouring slope; and is, notwithstanding all these advantages unproductive, *because it does not contain the chemical ingredients which plants require for their nourishment.*" An inspection of the analyses of the rocks from which the soils of this country are derived, will show you that they are capable of supplying these chemical ingredients in very different proportions, and will also convince you that the only certain method of estimating the agricultural capabilities of any particular soil, is by acquiring a knowledge of its chemical composition.

CHAPTER VII.

EFFECTS WHICH THE GROWTH OF PLANTS PRODUCES UPON THE SOIL, AND PLANS ADOPTED FOR MAINTAINING ITS FERTILITY.

136. HAVING in the preceding chapters described the conditions which are necessary for the existence of plants, and also the sources from which the materials that we discover in their structure are derived, we may now with greater advantage proceed to the consideration of the effects which the growth of those cultivated by the farmer has been observed to produce upon the soil, and also of the various plans which have been adopted for the purpose of maintaining its fertility or of increasing its natural capabilities.

Observation teaches us that nature, without the aid of man, provides food in sufficient abundance for the growth of the herbs and trees with which she clothes the surface of the uncultivated soil; and in the infancy of society the wild roots, herbage, and fruits of the field and forest were sufficient for the support of the wandering tribes that were thinly scattered over the earth. But as population increased, and men associated together in numbers in cities and villages, the necessity of producing, in the vicinity of their habitations, a larger supply of vegetable food than the soil spontaneously afforded, laid the foundation of AGRICULTURE. For centuries the knowledge which in these countries was possessed of the cultivation of plants was extremely limited, generally only a few vegetables occupied the attention of the farmer, and it is known, that many of the plants which are now highly esteemed for food, were at one time useless weeds; thus, the potato in its wild state in South America, travellers tell us, would scarcely in the produce of an acre afford food sufficient to sustain an Irish family for one day (Darwin): the peach of our gardens is said in its original state among the mountains of Hindostan to bear a bitter and poisonous fruit, and the now valuable turnip, when uncultivated, is found to yield a bulb not much larger than a pig-nut. The highly nutritious grain crops also that we now grow upon our farms, in their natural condition contained but a trifling amount of nutritious matter, but by cultivation they have been made to store up in their seeds that large amount of gluten and other flesh-forming principles for which they are at present so highly valued.

137. The main object of the farmer is to improve and develope the wild plants of the field, or to keep those which in the course of cultivation have been increased in value in proper condition; for experience has taught him that if he neglect his duty they gradually deteriorate, and become again worthless for food. It is evident that he cannot properly understand his business or expect to assist its progress without such knowledge of the materials of his fields, and of the influence which the air, the water, and the soil, exercise upon vegetables, as I have in the preceding chapters endeavoured to communicate.

138. At a very early period, farmers were led to perceive, that a close connexion must exist between the soil and the kinds of plants produced upon it, that the wild plants of the upland were different from those of the marsh, and that every district had its peculiar flowers and grasses. It was only, however, when chemistry had come to their assistance, that the true nature of the connexion became intelligible. We now know that certain plants flourish in some situations, and refuse to grow in other localities, because in the former the soil is capable of yielding the materials which are requisite for their full development, while in the latter it is incapable of supplying them with these materials.

139. *Nature of Exhaustion.*—Experience has also taught the farmer that though a field may be fertile, that is, furnished with the earths, alkalies, and other materials essential to the development of plants, yet that if the same crops be grown upon it for a great number of years in succession, it will sooner or later become incapable of yielding remunerating harvests, unless assisted by art.

Some useful information respecting the effect which the growth of crops is capable of producing upon the soil may be obtained by considering the practice of farmers in other countries. When the Irish emigrant in America burns down the trees of the ancient forest in his new settlement, and commits the seed to the freshly broken-up ground, he is astonished by a produce far exceeding anything to which he had been accustomed in his former experience, and for years he obtains immense crops of rich grain without the necessity of manuring or any apparent falling off, and congratulates himself upon the possession of a farm of inexhaustible fertility. Such is the case at present in many of the newly settled states, the soils of which are supposed by their cultivators to possess some peculiar qualities different from those of the old world. But the same thing was observed in the tobacco lands of the early settled southern states, where we are told wheat and tobacco were produced in succession, without manure, for upwards of a hundred years; but at last a time arrived when these lands would scarcely return the seed, and the same thing must happen in the other states if the same injudicious system be pursued. Formerly in the plantations of our West Indian colonies, sugar could be produced without any necessity for manuring the sugar-cane plantations, but at present that is impossible, and the planters are obliged to send to this country and to England for the materials which their exhausted fields require, or, as is done in some settlements, remove to other districts where the soil has been less injured. Now the so-called virgin fields of North America are not different in composition from what the soils of Ireland were, at the time they were first broken up by the plough. Waving forests once covered our hills, and their remains for centuries enriched the soil with mineral ingredients, but as population increased, our husbandmen, like the farmers of Virginia, grew upon them crop after crop of scourging grain, and fed upon them flocks of cattle which were exported to other countries without any return being made for the thousands of tons of materials thus taken away. But our farmers did not know that in their crops and cattle they were selling the materials of their fields, nor was the planter in British Guiana until lately aware, when he burned the crushed sugar-canes and threw away the ashes, that they were capable of supplying to his soils nearly all the ingredients which the crop had withdrawn from them.

140. The soil, you have seen, is produced either by the crumbling down of the bed of rock upon which it rests, or by the materials transported by water from other parts of the country. It can contain only the mineral substances of which the rocks are composed, and some of the most important of these, we have seen, exist in exceedingly minute quantities, and being by decomposition rendered soluble in water, may be carried away by the action of rain. At all events, the available stock of materials in even the best soils being limited, a time must

arrive when the most fertile soil in the country will be deprived of its power of production. I have already, in chapter iii. given an account of the characters of the substances which plants extract from the earth for their nourishment, and also directed attention to the fact that *the different crops which the farmer cultivates, take up these substances in unlike proportions* (55). I shall now return to this important subject, and consider more fully the peculiar action which the crops usually grown in the country exert on the soil. It is to be regretted that so little of the information which I am about to communicate, is based upon analyses of the plants of our own island. This great want, I hope, before many years will be supplied, and we will then be enabled with greater advantage to devise plans for the economical management of our farming operations. I will, in the following table, give the per centage composition of the ashes of the crops most important to the Irish farmer.

141. This table will be found interesting as showing the relative proportions in which the ingredients of the soil enter into our crops, and it becomes of the greatest practical value, when we calculate from it the amount of these substances, which are every year taken away from a farm in the course of cultivation. In Ireland we are destitute of that information, respecting the acreable produce of the different parts of the kingdom, which would be desirable in inquiries of this kind; and very few of our farmers have any accurate return of the proportions of grain and straw yielded by their grain crops, or of roots and leaves produced by their turnips and other root crops.

142. An examination of the annexed table, and also of the tables given in chapter iii. pages 49 and 50, in which the amount of dry matter and of ash contained in the crops usually grown by the farmer is stated (57), will show you, 1st, That the absolute quantity of the ingredients of the soil which plants abstract during their growth, varies with the kind of plant examined, and also with the part of the plant. Thus the proportion of ash which a hundred pounds of dried wheat leave when burned, is only about two pounds; while the same weight of dried clover hay, and of the dried bulb of the turnip, affords more than seven pounds, and the dry leaves of cabbage from eighteen to twenty-six pounds.

Comparative view of the average composition (in 100 parts) of the ash or inorganic matter of the following plants :—

Name of Plant.	Potash.	Chloride of Potassium.	Soda.	Chloride of Sodium.	Lime.	Magnesia.	Oxide of Iron.	Sulphuric Acid.	Phosphoric Acid.	Carbonic Acid.	Chlorine.	Silica.	Amount of ash in 100 parts of the dry plant.
Wheat	23·72	....	9·05	....	2·81	12·03	0·67	0·24	49·81	....	....	1·17	2·0
Wheat Straw	12·44	....	0·16	....	6·70	3·81	1·30	5·82	3·07	....	....	65·38	7·0
Oats	26·18, and soda	....	....	....	5·95	9·95	0·40	10·45	43·84	....	0·26	2·67	4·0
Oat Straw............	19·14	....	9·69	....	8·07	3·78	1·83	3·26	2·56	....	3·25	48·42	5·1
Barley	20·77	....	4·56	....	1·48	7·45	0·51	0·79	31·69	....	....	3 2·73	2·5
Barley Straw	6·31	....	0·61	....	9·53	3·22	0·83	1·63	3·08	....	0·97	70·58	6·0
Rye	32·76	....	4·45	....	2·92	10·13	0·82	1·46	47·29	....	....	0·17	2·3
Rye Straw............	17·36	....	0·31	....	9·06	2·41	1·36	0·83	3·82	....	0·46	64·50	3·6
Flax-seed (Riga)	17·59	....	6·92	....	8·46	14·83	1·25	2·47	36·42	....	0·17	10·58	4·9
Flax Straw	7·00	....	15·68	5·87	17·79	4·13	5·13	9·38	8·44	10·93	....	14·48	4·5
Turnip bulb (Swede)..	39·82	....	10·86	....	12·75	4·68	0·89	13·15	6·69	....	3·68	7·05	7·6
Turnip Tops	28·65	....	5·41	....	23·27	3·09	0·86	12·52	9·29	....	16·05	0·86	17·0
Carrots	32·44	....	13·52	6·50	8·83	3·96	1·10	6·55	8·55	17·30	....	1·19	5·1
Mangel Wurtzel	24·79	....	13·75	29·41	1·95	2·11	0·60	3·37	3·08	18·32	....	2·57	6·3
Beans................	42·13	0·34	0·90	1·90	8·65	6·55	0·36	4·50	31·87	1·94	....	0·88	3·01
Bean Straw	21·26	0·90	4·56	9·05	21·29	4·88	0·90	3·21	7·35	22·73	....	3·86	6·12
Peas	40·19	1·42	0·65	0·68	6·32	6·57	0·59	5·68	34·81	1·82	....	1·24	3·10
Pea Straw	17·17	....	2·48	3·57	37·99	6·73	1·76	5·66	4·50	14·74	....	5·36	7·57
Potato	55·75	....	1·86	....	2·07	5·28	0·52	13·65	12·57	....	4·27	4·23	4·00
Potato Tops	28·02	....	16.26	....	16·90	7·09	1·05	6·88	7·62	....	12·33	3·85	18 to 25
Red Clover Hay	14·85	2·96	1·40	2·36	35·39	11·22	0·97	4·18	6·35	16·93	....	3·34	7·99
White Clover Hay	14·33	....	3·72	4·94	26·41	8·15	1·96	7·21	11·53	18·03	....	3·68	8·73
Italian Rye-Grass in seed	10·77	....	0·13	5·58	12·29	2·64	0·30	1·31	6·32	....	....	60·62	6·40
Cabbage....	11·70	....	20·42	....	20·97	5·94	0·60	21·48	12·37	....	5·77	0·75	18 to 26

2d. That different plants, as has already been stated (55), though requiring all the mineral substances described (42), invariably select different proportions of particular kinds of matter for their nourishment, the root crops, for example, requiring large supplies of the alkalies, and the clover crops of lime, &c.

3d. That not only do our field crops exhibit a partiality for certain matters of the soil, but that *different parts of the same plant select dissimilar quantities of these substances*; thus the table shows us that while the straw of wheat yields an ash containing so much as 65 parts in the hundred of silica, the grain contains but a trifling amount of that substance; and that while the ash of the straw affords only 3 per cent of phosphoric acid, the inorganic matter of the grain yields 49 per cent. If you glance at the composition of the potato tuber, you will find that it is distinguished by containing a very large proportion of the alkaline substance potash, and a small amount of lime, while for the development of the tops, a considerable quantity of lime is required. The discovery of the unlike proportions in which the ingredients of the soil enter into the structure of the different parts of plants leads to important conclusions, and is capable of affording to the practical man a rational explanation of many things which appeared unaccountable to him in the growth of his crops. It teaches him, that as the different parts of the plant require the materials of the soil in different proportions, a crop may at one period of its growth thrive vigorously, and at another droop away; that a crop of wheat, or any other grain, may spring up with luxuriant growth, and promise a rich return, yet form but a poor and starved-looking seed, and again, how a plump and healthy head may be produced, while the straw thrown up is weak and stunted. It enables him also to understand how one soil, or one district of country, may refuse to yield profitable returns of certain crops, and yet afford ample food for plants of a different race.

143. *Modes adopted for improving the soil and maintaining its fertility.* There are three methods which have been adopted for this purpose, viz: *Fallowing, the alternation of crops, and the application of manures.* The first of these, termed *Fallowing,** consists in ploughing up the land into ridges at

* The term *fallow* is supposed to be derived from a Latin word signifying yellow, the land when in fallow presenting a yellow appearance.

the beginning of winter, and allowing it to remain in that state, exposed to the action of the weather. By this means the rocky particles of which the soil is composed, by the influence of the gases of the air and moisture, are gradually made to crumble, and the alkalies contained in them set free in a proper state to be taken up by plants. It is evident that the various mechanical operations of the farmer, such as frequent ploughings, &c. must facilitate this decomposition of the mineral matters of the soil, and serve to improve its productiveness. It was formerly supposed that the fallowing of land was indispensable to renew its fertility when exhausted, and that plants grown upon it separated from their roots certain excrements which it was necessary should be decomposed by free exposure to the air, and that by so doing the land was "sweetened" and rendered again fit for bearing crops. Many philosophers, however, consider that it has not been satisfactorily proved that plants give out organic matters from their roots, and are of opinion that the benefits of fallowing are to be ascribed to its facilitating the liberation of the inorganic principles of plants (42) which were locked up in the soil. By this system, however, the farmer was obliged to dispense for one year with any return from his field, either as food for man or animals, and at present it is but seldom employed in advanced agricultural districts, except on the most stubborn clays where the thorough drain, and other means of improving the texture of the soil, have not yet been adopted. The introduction of what are termed *green crops* into the period formerly occupied by the unprofitable fallow, has not only produced a complete revolution in our system of husbandry, but greatly increased the produce of this country.

144. *Rotation of crops.* A field, if made to produce the same crops for a number of years in succession may, as has been shown, in the grain and cattle sold off the farm, be impoverished by the loss of all the inorganic matters which it contained in a fit state to serve plants for food, and thus suffer a *general* exhaustion; or it may by the growth of a plant requiring *chiefly* the alkalies or lime, supposing the *active soil** to contain the usual amount of these ingredients, be

* The term *active soil* has appropriately been employed by an English chemist, Dr. Daubeny, to denote that portion of the soil of a field, in which the mineral matters required by plants exist in a condition capable of being taken up by the growing crop.

rendered by their loss incapable of supporting crops requiring a large supply of these matters, such as turnips and clover, and yet be capable of affording sufficient nourishment to plants which are found to select chiefly materials of a different kind. Experience taught that whilst crop after crop of the same plant materially exhausted the soil, the injury produced by changing the crops grown was not so great; and even before chemistry had enabled us to understand the effects produced by the growth of plants, farmers in many advanced districts, were induced to put a limit to the number of crops of the same kind grown in succession.

145. In considering the effects which the different kinds of plants exert upon the soil, it is necessary to recollect what has been stated, that not only do the different plants of the farm give a preference to particular kinds of food, but that the different parts of the same plant require different proportions of these materials for their growth. Such being the case, it is obvious that the exhausting effect which the production of any crop exerts upon the soil, will be influenced in a great degree by the purpose for which it is cultivated. Thus, plants like wheat, oats, barley, beans, peas, and flax, cultivated for their seeds, which are collected and used for food or sent to market, require a large supply of mineral materials and especially of phosphoric acid, a substance which you are aware is contained in very small amount in even the most fertile soils, and must therefore produce a different effect from the crops, such as potatoes, turnips, mangel-wurtzel, and clover, which we grow for the sake of their roots or foliage, or of flax when pulled before the seeds come to maturity. The study of the food of plants, therefore, points out to us the propriety of alternating with the wheat, and other crops which require for the formation of their seeds a large amount of nitrogen and phosphates, others, like the foliage and root crops, which do not contain the same amount of these substances, and are besides capable of condensing from the atmosphere a larger amount of its materials. In many districts in Ireland the farmers yet act with the same kind of thoughtlessness* that distinguished the early settlers in North America; they scourge the soil with crop after crop of grain until it will

* Improvements in practice are of slow progress. Even in the County of Antrim, which can boast of so many intelligent farmers, I have been shown fields producing a seventh crop of oats.

scarcely return the seed, and then leave it "to rest" in unprofitable pasture. The same mode of cropping was common in many parts of England before the introduction of what has been termed the Norfolk system, which led the way to the improved management of the soil which at present distinguishes the North of England, and which has been followed and improved in Scotland, and is gradually making its way into this country. In this system the land is every year made to produce food by a skilful application of the principles which have been laid down.

146. The investigations which have been made within the last two or three years have led to some curious observations on the composition of the ashes of plants, which, if corroborated by future researches, will be of great practical importance. It is known to the chemist, that in the mineral kingdom, certain substances are found to replace one another in the composition of minerals; thus, soda in some minerals takes the place usually occupied by potash, &c.; and in plants a similar curious substitution of one substance for another has been detected. Thus, in the ashes of clover grown upon soils rich in potash and poor in soda, the former of these substances is found in large quantity, while in soils in which soda is abundant and potash deficient, the soda is found to occupy the chief place in the ashes of the plant. The same thing has been discovered in other plants. The ash of the oak, for example, is usually found to contain potash, but on the sea-coast of North America, at Long Island, soda has been found to take its place (Gardiner). The study of these curious substitutions opens an interesting field to the agricultural chemist.

147. The practical rules to be deduced from the foregoing observations are—

I. That plants which require *chiefly* the same kind of materials for their support should not be grown in succession.

II. That as the effects which different crops produce upon the fertility of the soil are influenced by the purpose for which they are grown, that plants cultivated for the sake of their *seeds*, as wheat, barley, oats, flax, should be made to *alternate* with those which are cultivated for their *roots*, *foliage*, or *fibre*, as turnips, clover, &c., and also hemp and flax when the seeds are not allowed to ripen.

III. That the greatest possible interval should be introduced in the rotation between plants of the same kind, by the growth of as great a variety of crops as the climate of the country will allow; thus, instead of the farmer confining himself to wheat, barley, oats, turnips, potatoes, and clover, he should cultivate beans, peas, vetches, mangel wurtzel, carrots, parsnips, beet, flax, hemp, &c.

148. *Influence of soil upon the quality of the crops.*—The remarkable difference in the quality of the grain produced upon soils differing in their composition, has long been recognised by experienced purchasers. I have been informed by an intelligent starch manufacturer in Belfast, that the wheat grown in the barony of Ards, in the County of Down, and in the neighbourhood of Bangor in the same county, is highly valuable for his purposes, while that grown near Armagh yields in general a much smaller amount of starch. Another manufacturer is so fully convinced of the superiority of the wheat of the neighbourhood of Bangor, that he willingly gives five shillings per ton above the market price for that produced in the parish of Balloo. The general statement on the subject is, that soils rich in organic matter or highly manured with decomposing animal or vegetable substances, afford a grain which is richer in gluten than that produced by lighter and more sparingly manured soils, and those of the slate formation. The above statement respecting the value of the wheat grown in some districts of the North of Ireland, seems to confirm the statement.

CHAPTER VIII.

MEANS ADOPTED FOR IMPROVING THE SOIL AND MAINTAINING ITS FERTILITY BY THE APPLICATION OF MANURES.

ANIMAL MANURES.

149. To maintain the fertile condition of the soil, it is necessary that the materials which are every year removed from it should be restored. It contains, in mineral matters, and in the decomposing remains of vegetables, an abundant, but not always available supply of these materials; so it is required that certain artificial means should be adopted, to bring its dormant powers into activity, to make the clay-slate and granite give up their alkalies, and to convert the insoluble silica contained in them into a state in which it can become soluble in water, so as to be taken up by the roots of plants. Analysis has taught us, that the different families of plants which we cultivate, exhibit a partiality for certain ingredients of the soil, and that the tendency of cultivation is to convert vegetables which, in their natural state, abstract but a small amount of phosphorus, and other elements, into powerful exhausters of those substances: thus, the wheat and other seed crops must find in the soil an abundant supply of the compounds of phosphorus, (53) or they will not come to perfection; and, as these compounds are contained, in such minute quantities, in even our most fertile soils, as to be discovered only by refined investigation, it is evident, that their power of producing full crops of such plants, without assistance, must be extremely limited. In the present state of the fields of this country, neither fallow nor the rotation of crops is sufficient to preserve them from exhaustion; and the application of certain matters to the soil, for the purpose of supplying its deficient ingredients, has been found necessary. From the earliest period, the use of MANURES in maintaining and increasing the productiveness of soils has been known to farmers, in various countries.

150. In considering the principles of manuring, you must bear in mind the effects which, as has already been explained, plants produce upon the soil. You have seen, that our crops appropriate certain matters, which become a part of their

structure, and the loss of which, by the sale of our farm produce, must as effectually impoverish our fields, as if we were, by a chemical process, to remove from them these ingredients. Crops of weeds spring up in neglected places, year after year, without any decrease in luxuriance, because they die on the spot where they have been produced, and restore, by their decay, the matters on which they had lived, and thus keep up the fertility of the soil; but it is not possible, in this manner, to maintain the productiveness of our cultivated fields. Only that part of the plant produced which is unfit for food, can be directly restored. But, although we cannot directly replace in the soil the seeds, the roots, and the fibre employed for food and clothing, Nature has so arranged, that all the materials which during their growth, they have abstracted from it, after they have fulfilled the important purposes for which they are cultivated, may, by the care of the husbandman, be collected and restored, for the production of new crops of vegetables. In the present arrangements of these countries, however, but little attention is devoted to these sources of manure; and farmers are every year obliged to expend large sums of money, in the purchase of substances to replace the materials of their soils, washed into the sewers and rivers of the country.

151. You have seen, that the power of the soil to yield crops, depends upon its containing a full supply of certain mineral matters, which serve for their nourishment. From the most remote periods, farmers have been accustomed to apply to their exhausted fields the excrements of animals and of birds, and have found that these manures were capable of renewing their fertility. It is only of late years, however, that the cause of the valuable properties of these matters has been satisfactorily investigated, nor is the explanation difficult to understand. The food consumed by man and animals becomes a part of their bodies.—The roots and grasses which the cow eats contain the mineral matters which gave fertility to the fields in which they were grown, so that these matters become a portion of the bone and flesh of the animal. The seeds, roots, and flesh which afford us food must, in the same manner, enter into our substance; and when the flesh of an animal is dried and burned, it is found, like the vegetable, to consist of two portions, one of which, similar to the *organic* part of the plant, is combustible and disappears (41), and a

mineral indestructible matter, which, resembling the ash of plants, consists of the ingredients that compose our fertile soils. The bones of animals, also, when burned, are found to lose a considerable portion of their weight, disagreeable smelling gases escape, and a mass of earthy matter remains in the furnace, to the composition of which I will hereafter have occasion to direct your attention, as it contains some of the most valuable materials required for the nourishment of plants. Thus, the bodies of both men and animals are derived from the same materials as the plants that we cultivate—both are from the soil—creatures of the dust: the plant *directly* deriving the materials of its growth from the minerals of the field and the gases of the air, and the animal *indirectly*, through the vegetable creation. Chemistry has clearly shown us, that the lime of our limestone mountains, the potash which exists in our granite rocks (120), and the phosphorus of our soils, by the wonderful arrangements of Providence, become food for our crops, and ultimately build up the structure of our bodies. Nor are these materials which Nature provides in the earth squandered; a wonderful economy is displayed in every part of creation. The matters which we receive in our food, which become blood, and flesh, and solid bone, are not allowed, even during life, to remain inactive. They have no sooner performed the office assigned to them, than they are discharged from the body; and, in the liquid and solid excrements, both of man and animals, we discover the mineral materials contained in the bread and the beef, the seeds and the roots, which had composed their food. (156), It has been calculated that, in the case of a horse, which consumes 15lbs. of hay and 4½lbs. of oats per day, 21 ounces of the mineral matters which the hay and oats took from the soil are taken into his system—in a year, about 480 lbs. of these. If the horse, in the course of a year, increase in weight 100lbs., and if, in this matter added to his substance, we discover only 7lbs. of the mineral substances received in his food, the remaining 473lbs. must have been discharged from the body—(Liebig.) These matters are actually found in the excrements. The following tables of the composition of the liquid and solid excrements of man will show you, that in them we have the same mineral matters which are discovered in the ash of our cultivated plants.

152. *Composition in* 1000 *parts of the urine of man:*—

Water	933·0
Urea	30·1
Uric acid	1·0
Free lactic acid,* lactate of ammonia, and animal matter	17·1
Mucus of the bladder	0·3
Sulphate of potash	3·7
Sulphate of soda	3·2
Phosphate of soda	2·9
Phosphate of ammonia	1·7
Common salt	4·5
Sal ammoniac	1·5
Phosphates of lime and magnesia, with traces of silica	1·0
	1000·0

153. The *solid excrements* of a man, according to the analysis of Berzelius, had the following composition:—

Water	733
Albumen, and other animal matters	185
Saline matters	12
Undecomposed food	70
	1000

154. When dried, the solid excrement contained, in 1000 parts, 132 of inorganic matters, which had the following composition:—

Carbonate of soda	8
Sulphate of soda, with sulphate of potash, and phosphate of soda	8
Phosphate of lime and magnesia, and traces of gypsum	100
Silica	16
	132

The matter, therefore, discharged from the body, like the food, and the bone and muscle which it forms, is a mixture of organic and inorganic substances. The liquid excrements especially, being rich in compounds of Nitrogen, and being characterized by containing *urea*†—a substance which, by the decomposition that urine, when discharged from the

* The name *Lactic acid*, or acid of milk, is given to the acid formed in sour milk, in the fermentation of the juice of the Turnip, and in the souring of the grains of the Distillery.

† *Urea* contains nearly 47 per cent. of nitrogen.

body, undergoes, is changed into a volatile salt (13) termed *carbonate of ammonia:* while the solid excrement also affords nitrogen, and the compounds of phosphoric acid—which are so valuable for the food of plants. *In these excrements, Nature supplies us with all that our fields require, to produce the richest crops.*

155. VALUE OF URINE AND NIGHT-SOIL.—It may be said, that experience had taught our farmers the value of the excrements of man, before chemistry had been directed to the improvement of agriculture; yet it remained for that science to discover upon what their action depended, and, though it has shown us that they contain the very ingredients upon which plants live, how little have we, in this country, profited by this knowledge; urine is not merely neglected by the farmer;—in all the large cities of the empire, how much money has been expended to remove it expeditiously beyond our reach! There was a time when our farmers could afford to cart the accumulated manure of their cattle to the sea-beach, to allow the water to wash it away, and was formerly done by the farmers on the coast of Antrim,—as is even yet practised by the peasants on the banks of the Wolga; at present, they collect the droppings of their cattle, and the litter of their stables and cow-houses, in their farm-yards, and apply it to their exhausted fields, after it has been exposed for months to the air, and its most valuable parts washed out by the rains. No wonder, then, that they must purchase foreign manures, and expend money in supplying their fields with the matters which they require, when the potash, the soda, and other soluble inorganic matters of their manure heaps, are thus neglected, and whole tons of fertilizing materials drawn from their farms are sold to our cities, where they are carelessly wasted, and allowed to pollute the atmosphere, and generate disease!

156. From what has been already said, (151) it is evident, that the value of excrements for manure will vary with the diet; thus, the people of a district where much animal food and bread are consumed, will afford a manure richer in fertilizing ingredients than where the inhabitants are poorly fed. On the continent, this is so well known by experienced farmers, that they will give a higher price for the house manure of certain districts, where the people use animal food, than for that produced where the diet, for a

considerable part of the year, is of a less nourishing description. In Flanders, night-soil and urine have long been regarded as the most valuable manures; and their careful preservation is an important feature in the husbandry of that country. By the Belgian farmer, the value of the liquid and solid excrements of an individual, is estimated at £1 17*s.* per annum,* and so carefully is every trace of these manures collected in the towns, that the public authorities are relieved from all the expense and trouble which, in this and other countries, are incurred in the removal of nuisances. In China, also, which has preceded us in so many of our boasted improvements, strict laws are enacted for the careful preservation of human excrements, and in every house, and along the highways, vessels are placed for receiving them. Travellers inform us, that they mix the night soil with clay so as to form it into cakes which are called *taffo*, and are exposed for sale in all the cities of the celestial empire.

157. *Preservation of human excrements, and methods of applying them to the soil.*—On the continent, where attention has long been properly directed to the subject, various plans have been adopted for the preservation of these manures. In Flanders, the farmers not merely carefully collect the excrements of their own neighbourhood, but purchase the contents of the cess-pools in the towns, and store them in tanks of sufficient capacity to contain all the manure accumulated during several months. They apply them in the liquid state—usually after the sowing has been completed, by conveying them from the pits, in casks, and distributing them over the fields.

158. In Paris a different plan is adopted. The contents of all the cess-pools of the city are taken away by night, to a place in the suburbs, where they are deposited in an immense shallow tank, where they are allowed for some time to remain; and, when the solid matters have fallen down, the liquid is made to run into a second tank, at a lower elevation, and again from it into a third basin, from which the clear liquid

* If we suppose, according to the calculation of Liebig, that the solid matter contained in the urine of an individual annually amounts to 67lbs of equal fertilizing value to genuine Peruvian guano; then if all the urine of a town like Belfast containing 100,000 inhabitants, was collected and applied to the soil, our fields would receive the enormous quantity of six million seven hundred thousand pounds, or nearly 3,000 tons of manure, which, at the ordinary selling price of guano, would be worth thirty thousand pounds.

is permitted to flow away into the sewers. The solid matter thus deposited, when it has acquired sufficient consistence to be shovelled out, is collected and dried, by exposure to the air under sheds. This manure is termed *poudrette*, and contains, in 100 parts, about 1·8 parts of ammonia. By this method, it is evident much of the valuable matters of the manure is lost, as a considerable proportion of its ingredients are soluble in water, and must be carried away in the liquid. There is also a great loss of ammonia during the drying, and the volatile gases evolved by the decomposition of the organic matters contained in it decrease the amount of its fertilizing ingredients so much, that this method of treating excrement has been justly condemned by the leading agriculturists of France. In England, within the last four or five years, the contents of the water-closets and cess-pools of London, and some other cities, have, to some extent, been purchased by farmers, and are removed, in their natural state, in waggons, constructed for the purpose; but, as the offensive odour of the manure has interfered with the general adoption of this plan, various methods have been tried, both to remove its nauseous smell, and to convert it into a more portable form; and, at the present time, several companies exist, which prepare manures from night soil and urine, by mixing them with gypsum, animal charcoal, and other substances.

159. Among these compounds, one, sold under the name of *urate*, has been highly recommended as a valuable fertiliser. It is said to be prepared by mixing burnt gypsum with urine, in the proportion of 10lbs. of gypsum to seven gallons of urine, and, after the solid matter has settled down, the liquid is drawn off. The manure so prepared contains the phosphoric acid of the urine, in combination with the lime of the gypsum, and also a small portion of organic matter. In addition to gypsum, some manufacturers of urate add to the excrements animal charcoal, which must add considerably to the value of the manure. Judging, however, from a sample which was lately examined in my laboratory, I do not consider it worth the price at which it is usually sold to the farmer, as all the valuable ingredients contained in it could be purchased, at a cheaper rate, from the manufacturing chemist.

160. At present, in England, considerable attention is directed to the application to agricultural purposes of the sewage

matter of towns, which, besides night soil and urine, contains the sweepings of the streets, and the refuse of sculleries. Two plans for this purpose have been introduced. According to the first, it is proposed to collect the sewage in tanks provided with forcing-pumps, to raise the liquid and the matters suspended in it over a "stand-pipe," of peculiar construction, from which, by a series of pipes, it might be conveyed into the country for a considerable distance, and applied to the fields by a hose. Mr. Chadwick, who has zealously advocated this method of applying manure, states, that he has found by experiment, that by means of a $2\frac{1}{2}$ inch hose, and a pressure of 80 feet, he could with the labour of two men, one to remove the hose and another to direct the nozzle, distribute 2,000 gallons of liquid sewage in an hour, which from analysis has been found equivalent to 3 cwt of guano, and 15 tons of stable dung, and would therefore be sufficient dressing for an acre of ground, at an expense of 6*d.*; while the cost of loading and spreading an equivalent quantity of stable manure on land close to the farm was about 11*s.* He estimates the total expense of the delivery of liquid manure, including the interest on the machinery and capital, at 1*s.* per acre. The hose can be made of strong canvass saturated with coal tar, which protects it from the rot. This method of applying the liquid of our sewers secures the preservation of all the matters of the manure, and must be regarded as preferable to any other plan, where the proper arrangements for the purpose can be obtained.

161. Within these few years many interesting trials of the value of sewer water, as manure, have been made in England and Scotland, the results of which have been most encouraging. Thus, on the property of the Duke of Portland, at Clipstone Park, a sterile sand has been converted into luxuriant meadow land by being irrigated with the drainage of a small village; and fields which were considered dear at five shillings per acre, rendered worth £11 per acre. In the neighbourhood of Edinburgh the most extraordinary effects have also been produced by the application of the drainage water of the city; "so that," as Mr. Smith of Deanston states, "land which let formerly at from 40*s.* to £6 per Scotch acre, is now let annually at from £30 to £40; and that from sandy land on the sea-shore which might be worth 2*s.* 6*d.* per acre, lets at an annual rent of from £15 to £20.

That which is nearest the city brings the highest rent, chiefly because it is near and more accessible to the point where the grass is consumed, but also partly from the better natural quality of the land. The average value of the land, irrespective of the sewer-water application, may be taken at £3 per imperial acre, and the average rent of the irrigated land at £30, making a difference of £27; but £2 may be deducted as the cost of management, leaving £25 per acre of clear annual income due to the sewer-water."

162. The second plan proposed is to collect the sewage matters in tanks, and, by the addition of slaked lime, made into a cream with water, to throw down their most valuable ingredients, and to collect and dry the deposit.* Though by this method of treating the contents of sewers a solid and portable manure is obtained which must possess considerable fertilizing value, yet only a part of the ingredients of the sewage is obtained, much of the Nitrogen present escapes in the form of Ammonia, and a considerable amount of the soluble inorganic or saline matters remain dissolved in the liquid which is allowed to flow away after the removal of the deposit.

163. What has just been stated of the valuable fertilizing qualities of human excrements, and the importance which is at present attached to their preservation in other countries, may, I hope, induce you to give greater attention to these manures. Night soil and urine may be readily converted into manures, and their offensive odour removed, by very simple means which should be known to every farmer. Thus, by adding to them coal-ashes or saw-dust, moistened with a solution made by dissolving the substance called "green vitriol,"

* The following is the composition of a specimen of the deposit, procured from sewage, by the addition of cream of lime, which, in the course of some experiments, undertaken at the request of the Corporation of Belfast, I had occasion to analyze. 125 parts of the deposit, dried at 212°, contained as follows:—

Organic matters, capable of yielding 6.925 parts of ammonia	81.25
Phosphate of lime (bone earth)	10.46
Sulphate of lime (gypsum)	2.00
Carbonate of lime	19.53
Lime	8.43
Magnesia	1.23
Alkaline chlorides	0.33
Sand, &c.	1.67
	125.00

(*Sulphate of Iron*), in water,* the escape of the disagreeable smelling gases will be prevented and the good qualities of the manure preserved. Even without the use of the solution of green vitriol, by mixing the excrements with the charcoal procured by burning peat with a smothered fire, a valuable compound capable of being applied with the drill may be prepared. In France the vegetable matter at the bottom of rivers is charred in close vessels, and advantageously employed for this purpose; spent bark, and burned clay, are also used. *Dry* peat mould is also a most valuable material for mixing with night soil, and is much employed by the farmers in Normandy and other parts of France; two parts of the peat mould, one part of gypsum in powder, and one part of night soil, form a mixture which may be at once applied to the soil and has been found to possess the greatest value as manure.

164. *Urine of the cow, horse, pig, and sheep.*—The *solid* excrements of the domestic animals have long been regarded as valuable manures, and have been employed from the earliest times to increase the fertility of the soil. But the value of the *urines* of animals has not until within these few years been properly understood; and in general but little attention is, in this country, paid to their preservation. It is however to be expected, that when instruction in the principles of agricultural chemistry is made a part of the ordinary education of the young farmer, the rich supply of the matters which plants require for their food, contained in those liquids, will no longer be disregarded.

The following table will make you acquainted with the amount of organic and inorganic matters which 1,000 parts of the urine of the cow, horse, pig, and sheep, and also that of man, are capable of conveying to the soil:—

	Man.	Cow.	Horse.	Pig.	Sheep.
Water, ...	933·00	921·32	910·76	978·80	960·00
Organic matters,	48·56	41·98	48·31	5·24	28·00
Inorganic matters	18·44	36·70	40·93	15·96	12·00
	1000·00	1000·00	1000·00	1000·00	1000·00

* 10 oz. of Sulphate of Iron may be added to each 20 gals. of urine.

165. The quantity of the urine discharged by the domestic animals, as well as the relative amount of organic and saline matters contained in it, will, however, like that of man, as has already been mentioned (156), vary according to the quantity and quality of the food consumed, and are also materially affected by the age and condition of the animal. You will be surprised to hear that the quantity of urine voided by an animal is not in proportion to the amount of drink which is taken; thus, it has been found by experiment that the horse, which daily requires several gallons of water for drink, does not annually afford a larger quantity of urine than man, whose daily drink does not exceed a few pints; the cow also does not, as the following table will show, yield an amount of urine in proportion to the water taken into the stomach. Thus:—

						lbs.
Man	annually affords	1,000 lbs.	of urine,	containing	of solid matter	67
Horse,	,,	1,000	,,	,,	,,	89
Cow,	,,	13,000	,,	;;	,,	1,023

The small quantity of urine voided by the cow and the horse,* compared with the enormous amount of water which these animals consume, is explained by the large amount of fluid which is constantly escaping from their surface in insensible perspiration, and also in the watery vapour which is given out from their lungs in respiration; while in man only about a tenth part of the liquid taken into the stomach is separated from the skin. If you refer to the table in page 114, you will perceive that the urine of the horse contains a larger amount of solid matter than any of the other liquids, and must therefore be capable of exercising a powerful effect upon plants.

166. The chief difference between the urine voided by the domestic animals and man, is in the composition of the inorganic or saline matters which it contains. In the urine of the horse and cow, merely a trace of phosphoric acid is found, the inorganic matter which it affords consisting chiefly of alkaline carbonates (43), sulphates (13), and common salt, while the urine of man and of swine is distinguished by a large amount of the compounds of phosphorus. The effects

* Boussingault found by experiment that a horse which in 24 hours drank 35 lbs. of water, gave only three pounds of urine.

which these liquids would produce when applied to the fields must therefore be very different. The urine of man and of the pig is specially adapted to promote the growth of our seed-crops, and that of the horse and cow for the root-crops, which require to be supplied with alkalies.*

167. To fix upon your minds what I have stated respecting the loss which our farmers experience by neglecting to economise the liquid excrements of the domestic animals, you have merely to calculate, from the information which I have given, the value of the fertilizing materials which are annually wasted, on almost every farm in this country. Thus, a farmer who keeps three cows and one horse, and collects merely the solid dung, allowing the urine to escape into the drains, loses annually in the cow urine (165) 3069 lbs. and in that of the horse, 89 lbs.; in all, upwards of 28 cwt. *of dry fertilizing matter, equal in value to the best Peruvian guano*, and which at the usual price of that substance would be worth £14, and be capable, without the addition of any other manure, of keeping seven acres of land in the most fertile condition.

168. *Solid excrements of the domestic animals.*—The dung of the cow and horse, and of the other domestic animals, is found to differ materially from the urine in composition; while

* Mr. M'Lean, in the *Transactions of the Highland and Agricultural Society*, gives the following report of the comparative value of urine, moss saturated with urine, and subsoil saturated with urine, in an experiment upon the hay crop of 1842.

Application.	Quantity of Urine per Imperial acre.	Quantity saturated with urine.	Value of Urine.	Value of matters saturated.	Weight of Hay.	Gain.
			s. d.	s. d.	st. lbs.	st. lbs.
Nothing........	——	—			125 10	——
Urine..........	2,500	—	52 2		300 00	174 4
Moss saturated	1,600	15	33 4	7 6	240 00	114 4
Subsoil do.	1,600	15	33 4	7 6	200 00	74 4

the liquid is deficient in phosphates, the solid excrement contains a large amount of these valuable compounds. Both together afford us all the elements necessary for the development of plants. The fresh dung of the cow and horse has respectively the following composition in the 100 parts:—

	Cow.		Horse.
Water	79.724	...	78.36
Organic matters	16.046	...	19.10
Saline matters	4.230	...	2.54

The composition of the saline matters of each in the 100 parts is as follows:—

	Cow dung.		Horse dung.
Phosphate of Lime	10.9	...	5.00
Phosphate of Magnesia	10.0	...	36.25
Carbonate of Lime		...	18.75
Phosphate of Iron	8.5	...	
Carbonate of Potash	1.5	...	
Sulphate of Lime	3.1	...	
Silica	63.7	...	40.00
Loss	2.3	...	
	100.0		100.00

169. The dung of the cow, however, usually contains a larger amount of water than stated in the above analysis; and as the chief portion of the nitrogen contained in its food is separated in the urine, it does not so readily run into fermentation, and is correctly regarded as affording a *colder* manure than horse-dung. The quantity of solid matter, you have seen, which is annually voided by the horse in the urine, does not amount to one-tenth part of that which is contained in the urine of the cow; and as the food which the former animal receives consists chiefly of the dry and nutritious grains, its solid excrement rapidly decomposes, and gives out much heat when placed in the soil; and hence it is frequently mixed with other manures for the purpose of inducing fermentation. From the rapidity with which it decomposes, much of the valuable qualities of horse-dung are usually lost to the farmer by allowing it to accumulate in the stable or farm-yard. Boussingault found that fresh horse-dung which, deprived of water, contained in the 100 lbs. so much as $2\frac{7}{10}$ lbs. of nitrogen, lost by fermentation

9.10lbs. of its weight, and afforded only one pound of that substance which it is so important to economise.

170. *The dung of the pig* usually contains about 75 per cent of water, and is generally regarded as affording a *colder* manure than that of the horse or cow; but as the pig is a general feeder, the manure which it yields will frequently be rich in nitrogen. On the continent it is much employed in the cultivation of hemp, but is supposed to give a disagreeable flavour when applied to the root-crops.

171. *The dung of the sheep* is of great importance as a manure in many districts, both in England and this country. In Wiltshire, the usual method of applying it is by folding the sheep on the bare fallow, and shifting the hurdles every night so as to distribute the manure over the field. On the light soils of Norfolk also, it has been found of great advantage to allow the sheep to consume the crops in the field, by which means the manure is trodden in, and its rapid fermentation prevented, and the ground at the same time consolidated. In the quantity of nitrogen which it contains, and consequently in its tendency to ferment, sheep-dung may be regarded as intermediate between that of the cow and horse. All these manures contain the ingredients which plants remove from our fields, and by their careful restoration to the soil you will supply your crops with the materials which they require, in the form best adapted for their nourishment. Experience has taught farmers how much the value of the manure which is produced by an animal, is influenced by the food with which it is supplied; and that a cow fed upon highly nutritious substances, such as bean-meal and oil-cake (77), yields a manure containing a larger amount of fertilizing matter than one fed upon straw and turnips.

172. It has also been found that *the quality of the dung of an animal depends upon its age and the purpose for which it is kept.* Thus, the dung of *growing* animals is not so rich in fertilizing materials as that of *full-grown* cattle. To enable you to understand how this is, it will be useful briefly to describe the changes which food is made to undergo when taken into the body. You will recollect that I stated to you in a preceding chapter (79), that the great bulk of every plant cultivated for food consisted of certain compounds produced by the union of the four simple elementary bodies, oxygen, hydrogen, nitrogen, and carbon; and that while one

class of these compounds, gluten, albumen, &c. was distinguished by containing a large amount of nitrogen, and was in fact almost identical in composition with the substance of the flesh of animals, another class of bodies—starch, sugar, fat, &c. was composed solely of carbon and the elements of water united in various proportions. You are already aware that the gluten, and other nitrogenized matters contained in the seeds and herbage which are eaten by animals, serve to build up their bodies—are converted into their substance; but in the greater number of plants used for food, the proportion of compounds containing nitrogen is exceedingly small as compared with those resembling starch and sugar in composition, the former on an average amounting to only 11 per cent, while the latter average from 70 to 80 per cent. "What," you will inquire, "becomes of the carbon which is eaten by animals?"

173. You may recollect that I stated (26) that an enormous amount of carbonic acid is given out in respiration. The air that we draw into our lungs in breathing contains only the one two-thousand-five-hundredth part of its bulk of that gas; yet, when we throw it out again into the atmosphere, its proportion is found to be increased so as to form two gallons in every hundred expired; a full-grown man, using vigorous exercise, giving out every day from his lungs as much carbonic acid as would be produced by the combustion of about fifteen ounces of charcoal. This separation of carbon in the form of carbonic acid from the lungs of animals, is indispensable to the continuance of life, and is made to serve an important purpose in the animal economy.

174. When a pound of starch or sugar is set on fire it burns and disappears, the carbon contained in it unites with the oxygen of the air, producing carbonic acid gas (22) and giving out heat; and the carbonaceous compounds, starch, &c. which the animal eats, are believed to undergo, *within the body*, by the influence of the oxygen of the *inspired* air, precisely similar changes as when burned, the carbonic acid gas being discharged from the mouth and nostrils, while the heat which is generated by their combustion, as it may be termed, serves to maintain that temperature of the body which health requires. Thus, you perceive that those compounds, though incapable of being employed in the formation of bone or muscle, are indispensable to animal life.

175. So much, therefore, of the carbon of the mixed food eaten by animals being thus separated in respiration, it is evident that the part which remains must become *relatively richer* in nitrogen and the other ingredients; and consequently, when expelled from the body in the liquid and solid excrements, be capable of exerting a more powerful effect as manure than *the same weight* of the unaltered food applied to the soil. It has been ascertained, by careful analysis of the food and excrements of a horse fed on hay and oats, that, while in the food, carbon and nitrogen existed in the proportion of 28 parts of the former to 1 part of the latter, in the dung there were but $10\frac{1}{2}$ parts of carbon to 1 part of nitrogen. Thus, the investigations of the chemist beautifully confirm the accuracy of the opinion long entertained by practical farmers.

176. After the above remarks, you will readily understand the explanation which chemistry affords of the difference in the value of the manure produced by young animals and full-grown cattle. In the droppings of a *full-grown* animal, you have seen, the food eaten is discharged improved in its fertilizing qualities; but, in the *growing* animal, much of the gluten and inorganic matter of the food is employed in the development of its bones and muscles; hence the dung discharged from the body is *not so rich* in nitrogen and saline matters. In *fattening* animals, the increase in bulk is produced not at the expense of the gluten and other nitrogenized matters of the food, fat, like starch, containing no nitrogen (78), and being formed from carbon, hydrogen, and oxygen only; nearly all the nitrogen therefore of the highly nutritious food which the animals receive is discharged in their dung.

177. *Farm-yard Manure.*—The refuse of the farm, the straw used for litter, mixed with the liquid and solid excrements of the cow-house, stable, and piggery, constitute what is termed "farm-yard manure," which has long been regarded as the most important source of the materials required for the growth of the farmers' crops. It is generally supposed that this manure must contain everything which plants require for their nourishment, and to be all-sufficient to restore fertility to any description of soil; but you will readily understand, from what has been stated respecting the variable composition of the excrements of animals, as well as of the plants produced on the farm, that it must vary exceed-

ingly in value, and in many cases be deficient in some of the most essential ingredients.

178. A slight consideration of the nature of the substances which compose the manure heap, will show you how much its value may be lessened by the ordinary wasteful practice of the farmers in this country. In the first place, it consists of a mixture of vegetable matters, which have been trodden under the feet of cattle, and saturated with their urine, and therefore in the most favourable condition for undergoing fermentation. In the course of some weeks after the mixture has been formed, you find, upon examining the heap, that heat is produced, and that a kind of slow combustion is going on within it. The effect of this fermentation or combustion is to break up the structure of the straw and other vegetable matters present, and, in the escape of the pungent smelling ammonia and other gases which fill the farm-yard with their odours, you perceive that some of the ingredients of the mixture have become volatile, and are escaping into the atmosphere.*

179. Now, every pound of ammonia which escapes, carries with it the nitrogen which would have been sufficient for the growth of 60lbs. of corn. As the fermentation of the manure proceeds, more and more of the organic matter present undergoes decomposition, and is converted into volatile gases; so that, after rotting for several months, its weight is found to have greatly diminished, and it has become a black, friable mass.† Nor is it merely the organic matters of the mixture that are lost. Considerable portions of the excrements of animals readily dissolve in water, and the tissues of the straw, leaves, and other vegetable remains, being broken up by the fermentation, the mineral matters

* If a piece of moistened *red* litmus test-paper be brought near a smoking manure heap, it will be rendered *blue*, and a glass rod moistened with spirits of salts (*muriatic acid*) will be covered with a white crust of sal ammoniac, produced by the union of the acid with the escaping ammonia.

† Some instructive experiments made on the continent show us how much manure is wasted by allowing it to remain exposed in heaps. Thus, a hundred loads of fresh dung were reduced at the end of

		Loads		Loads
81	days,	to 73.3,	sustaining a loss of	26.7
254	,,	64.4	,,	35.6
384	,,	62.5	,,	37.5
493	,,	47.2	,,	52.8

which they contain are rendered soluble. The first shower of rain, therefore, which pours upon the heap more water than it can soak up, flows away, carrying with it some of the phosphoric acid, sulphuric acid, potash, and other valuable ingredients, which had given fertility to your fields. These substances, with some of the ammonia, which is exceedingly soluble in water (16), are swept into the drains.*

Thus, though the manure heap is formed of materials rich in all the substances which enter into the composition of our crops, as usually managed, it must, when applied to the land, be deficient in much of its original fertilizing power.

180. Farm-yard manure usually contains about 70 per cent of water, 20 per cent of organic matters, and 10 per cent of earthy and saline matters; and it is calculated that, on the average, 10 tons of it convey to the soil about 1 cwt. of ammonia and 78lbs. of phosphoric acid, and the same amount of potash. From the great variety, however, of materials composing it, every sample of this manure will vary widely in composition, and an account of the analyses of it which have been published, would convey but little information to the farmer. It will be of greater consequence to consider how the loss of the volatile matters which are set free during fermentation, and also of the inorganic matters which are so liable to be washed out by our frequent showers, may be most effectually prevented.

In wet weather, you will observe on every part of the country a black stream oozing from the farm-yards, and

* The drainings of farm-yard dung have been analyzed, and found to be exceedingly rich in fertilizing matters. The following is the composition of an imperial gallon of the liquid, examined in the Laboratory of the Agricultural Chemistry Association of Scotland:—

Ammonia	21.5 grs.
Organic matter	77.6
Inorganic matter, or ash	518.4
	617.5 grs.

The inorganic matter contained in the liquid consisted of

Alkaline Salts	420.4 grs.
Phosphates of Lime and Magnesia	44.5
Carbonate of Lime	31.1
Carbonate of Magnesia, and loss	3.4
Silica, and a little Alumina	19.0
	518.4 grs.

flowing away unheeded into the sewers; and in the hot days of summer, the pungent odours which are given out from the carelessly heaped together contents of the stables, will show you that the farmer, ignorant of his profession, is unconsciously allowing the most active matters of the manure to escape into the air.

181. *Management of farm-yard manure.* To secure all the good qualities of the fertilizing substances collected together in the manure heap, it will not do to leave it to chance. You must not allow the air to run away with one part, and the rain with another part, of its most useful matters. It is of the utmost importance that you carefully preserve and restore every particle of the materials abstracted from your fields. All the arrangements of the farm-yard and offices should be made subservient to this purpose, and the money expended in providing a proper receptacle for the manure will be fully repaid in the increased luxuriance of your crops.

You should not, as too frequently done, allow the manure, upon its removal from the cow-houses and stables, to be spread over the farm-yard, but have it immediately carried to a place prepared for its reception, at a convenient distance from the office-houses. This dung-stead should, if possible, be placed in the north side of the farm-yard, and if the ground be porous, it should be puddled with clay and paved, so as to be rendered completely water-tight. It is not necessary that it be excavated below the surface of the yard, but it should be made to slope, so that the liquid which escapes from the manure may flow into a water-tight reservoir provided for its reception. In some of the best agricultural districts on the continent, the manure-stead is separated into two divisions by a tank, usually about four feet deep, and of breadth proportionate to the size of the heap; the sides and bottom of this reservoir are well puddled with clay and lined with masonry; and the more effectually to convey into it all the drippings from the manure, the sides of the heap are surrounded with a paved channel. At one extremity of the tank a strong wooden pump is fixed, by which the liquid can, at pleasure, be discharged over the manure, by means of a canvass hose, or wooden spouts, or pumped into casks to be conveyed to the fields.

All the farm buildings should be spouted, and the water from the spouts, as well as that which falls upon the yard, should be conveyed away, by drains so constructed that it may be allowed to flow over the adjoining fields, or used to dilute the contents of the tank. The liquid from the byres and stables, which has not been absorbed by the litter, and also the drainage from the farm-house, should be conveyed to the tank by drains, which are readily formed by inverted draining-tiles bedded in clay, and covered over with boards or flags. To prevent any loss of space, the tank, when placed across the manure-stead, may be covered with a close wooden grating, and the dung piled upon it, by which means the evaporation of the liquid will be prevented, and any escaping gases absorbed by the manure. Some farmers consider it necessary to cover the manure with a roof, but when the yard is carefully drained, it may be dispensed with, as the rain which falls upon the heap will tend to prevent too rapid fermentation, and any matters dissolved out will be found in the tank.

182. The manure should be evenly spread upon the dung-stead, and the sides of the heap preserved perfectly straight, and care should be taken to prevent the temperature rising too high. When it rises above 82 degrees of the thermometer, it should be moderated by an application of liquid from the tank. Fermentation should not be allowed to proceed farther than when the straw commences to lose its consistence. At this period it is admirably adapted to promote the growth of plants, and when it is not convenient to remove to the fields, some sulphuric acid, sulphate of lime, or sulphate of iron, should be added to the liquid before pumping it on the heap. "Farmers," says an able continental writer on this subject, "often hesitate to make the necessary arrangements to save their liquid manure, because they imagine they can obtain it in very small quantity. They do not consider that the little stream of liquid manure which trickles from their dunghill runs during nearly the whole year, and increases with every rain. With 6 or 8 horses, as many cows and oxen, and 100 sheep, there may be obtained more than 200 hectolitres* yearly, when the arrangement to collect it is made in a manner by which none will be lost. With this quantity distributed in the fields, many thousand pounds

* A hectolitre is about 22 gallons.

more of fodder will be harvested than could have been procured without it."*

Though many of our small farmers cannot be expected to construct tanks and receptacles for manure such as have been above described, yet even the poorest holder of land in this country has it in his power to do something to prevent the present shameful waste of the materials which his crops require, and the neglect of which, you are now prepared to acknowledge, must as certainly tend to the exhaustion of his fields, as if he were every year to throw a portion of their produce into the sea. Remember that if you wish to succeed as a farmer, it is not enough to possess a kindly soil or to carry off the first prizes at the ploughing-match, if you are every year obliged to purchase those matters to feed your crops which are allowed to escape into the air, or to be washed into the sewers from your neglected manure heap. How much money expended in the purchase of guano, and other foreign manures, might be saved by a careful economy of the ingredients abstracted from your fields!

183. If you refer to a preceding chapter in which the method of preparing pure ammonia is described (*page* 28, *note*), you will find that that substance, so important to vegetable life, is readily separated from certain compounds in which it exists, by mixing them with quicklime; thus, for example, when the salt termed sal ammoniac (19), in which that gas exists in chemical combination with muriatic acid (*page* 29), forming a compound free from smell, is mixed with *caustic* lime, the acid unites with the lime, while the ammonia escapes, giving out its characteristic odour. Soda, potash, and magnesia, in the caustic state (43, 47), also possess the property of *decomposing* the salts of ammonia; hence when the farmer, as is so frequently practised in some parts of Ireland, adds quicklime to his manure heap, the carbonate of ammonia (154), produced by the decay of the nitrogenised matter contained in it, is decomposed, and the volatile ammonia expelled into the atmosphere. As it is of

* A simple and perfectly effectual plan of distributing the liquid manure, is to affix a piece of board, about a foot square, opposite to the hole in the end of the manure barrel, so that when the plug is withdrawn, the liquid, as it gushes out, may strike against it. By this method the manure is spread out with considerable regularity, as the cart on which the barrel is fixed passes slowly along.

vital importance to the farmer that none of this ingredient of manure, so essential to the full development of his crops, should be allowed to escape, one or other of the chemical substances above described should be employed. When describing the method by which Liebig detected the ammonia existing in the atmosphere (19), I mentioned that he added to the rain water in which it was dissolved a small quantity of muriatic acid, by which the heat used in evaporating the water was prevented driving it away. Several other acids also possess this property; and when the salts which sulphuric acid forms by combining with iron, *green vitriol* (163), and with lime, *gypsum*, are mixed with decomposing manure or night soil, the acid enters into chemical combination with the ammonia and converts it into a solid compound, which, though soluble in water, and therefore capable of being taken up by plants, is securely *fixed* in the manure heap.*

184. It is not necessary that the small farmer should construct an expensive tank; a treacle hogshead, or even a large tub sunk in the ground close to the manure heap, will be found a very good substitute for it. In a small establishment, nearly all the liquid manure of the stable and cow-houses may be completely absorbed by the litter; or, where enough of straw cannot be obtained, by spreading under the cattle dry peat-mould, saw-dust, or even dry soil from the fields, as is done by the careful farmers in many parts of this country. The manure, when removed from the houses, should be placed in a sheltered position upon a bottom of earth well beaten down, so as to be rendered as retentive of moisture as possible, and made to slope towards the tub; a trench dug round the heap will serve to prevent the entrance of surface water. In districts where peat mould can be conveniently procured, its use will be found of great value to the farmer; by adding a layer of it occasionally to the manure

* The teacher may usefully impress the above remarks on the minds of his pupils, by placing before them some *sal ammoniac* and *quicklime*, and allowing them to examine them. Neither of these substances, he can show them, gives out any smell; but by rubbing together in the mortar one teaspoonful of the former with two of the latter, the pungent odour of ammonia will be immediately evolved. The nature of the escaping gas may be *tested* (11) by bringing near the mortar a piece of moistened *red* test-paper, which will be rendered *blue* by the alkaline gas. The property which certain substances possess of fixing ammonia may be convincingly shown by pouring into the mortar a teaspoonful of *spirits of salts*, when the pungent odour of smelling salts will be destroyed.

heap, and moistening it with liquid from the tub, the fertilizing qualities of the manure will be greatly increased.

185. It is considered indispensable by many persons when the liquid manure is to be applied directly to the fields, that it should be allowed to remain for some time in the reservoir, that it may undergo fermentation. But this plan would require tanks of greater capacity than are likely to be provided by the greater number of farmers. When used as a top-dressing, if diluted with four or five times its bulk of water, or the washings of the byres and dwelling-house, it may be applied without apprehension; for manuring the ploughed soil before sowing, it is unnecessary to dilute it. On the continent, the farmers consider the liquid manure to be peculiarly adapted for the cultivation of potatoes and other root-crops; and in Belgium, light sandy soils, which in this country would be regarded as worthless, are made to yield splendid crops of hay by frequent applications of it.

186. From reflecting upon the loss which is experienced in the ordinary method of treating manure, many intelligent farmers in this country have adopted the plan of conveying the fresh unfermented dung directly from the stable to the fields, and of allowing it there to undergo the changes required to enable it to assist vegetation. Opposite opinions respecting the propriety of this practice are held by some of our most experienced cultivators. But from a careful consideration of the subject, and from observing the success with which this method has been followed, both in our own and other countries, I would advise you, instead of allowing the manure to accumulate in heaps, to convey it as frequently as possible to your fields, and to bury it at once in the soil. While the action of rotten dung is soon exhausted, the fresh manure affords a steady supply of food to plants by its gradual decomposition, and the heat given out by its decay, the benefit of which is usually lost to the farmer, must also contribute to promote vegetation. It has been objected that for crops which, like the turnip, require to be rapidly pushed forward in the first period of their growth, fully fermented manure is necessary, but for these crops a small quantity of guano or dissolved bones should be invariably applied with the farm manure. This practice is followed with great success on the well-managed farms of the Messrs. Andrews near Comber, County Down.

187. *Guano.*—One of the most extraordinary features in the agriculture of the last half century is the importation into this country of enormous quantities of various animal substances, for the purpose of being employed in increasing the produce of our farms. Every part of Europe has been ransacked for bones to manure the fields of England and Scotland, and within the last four or five years thousands of tons of the droppings of sea-birds, deposited on the coast of South America and Africa, have been purchased for the same purpose. It has been stated that between 1841 and 1844, England imported not less than 70,000 tons of this manure, the very name of which was a few years ago scarcely known in this country. Thus, whilst we neglect the fertilizing materails at our doors, we have not hesitated to send 5,000 miles for the mineral matters contained in the excrements of birds.

188. It is unnecessary to describe the characters of the substance which is termed guano, as that manure is now well known to every farmer. It consists of the excrementitious matter deposited by sea-birds, which in certain parts of the world congregate in immense flocks, covering the islands and promontories which they frequent with their droppings. It appears to have been used from the earliest times by the natives of Peru, who by its assistance and the employment of irrigation, were enabled to produce rich crops of grain from sterile sandy soils. Before the year 1841, though small quantities of it had been brought to this country, it attracted but little attention, and was regarded merely as an agricultural curiosity until Lord Stanley, at the meeting of the Royal Agricultural Society of England, held in that year at Liverpool, gave an account of its extraordinary fertilizing qualities; and the successful results which followed the trials which were made of it, at once established its character as a most important addition to our animal manures.

189. The first guano brought to this country was from the islands near the coast of Peru, and was sold at from 22*s.* to 28*s.* per cwt.; but as the demand for the manure increased, another deposit of it was discovered on the island of Ichaboe on the coast of Africa, which however was in a short time exhausted. Other deposits, both on the coast of America and Africa, have since been found out, and at present afford a considerable supply, though of inferior value to the Peruvian and Ichaboe guanos.

190. In guano, we find all the inorganic materials which existed in the food of the birds by which it has been deposited, for, by a peculiarity in the structure of birds, both the liquids secreted by the kidneys and the solid contents of the bowels are discharged from the same aperture, and thus both the soluble salts which had been taken into the circulation, and the undigested matters of the food are contained in these deposits. In countries like Peru, where rain seldom falls, the soluble parts of the excrements dried up by the warm sun, remain for centuries, and the substances containing nitrogen (*uric acid*, &c.), are not decomposed into volatile compounds, so that in the best preserved samples of Peruvian guano the smell of ammonia is scarcely to be perceived, while in samples of the manure brought from other places not so favourably situated for its preservation, the alkaline salts have nearly disappeared, and a strong pungent ammoniacal odour is evolved by the decomposing nitrogenised matters, thus while genuine Peruvian and Bolivian guanos yield in general from 10 to 16 per cent of ammonia, the guano brought from Patagonia consists chiefly of the insoluble Phosphates (53), and affords only about 3 or 4 per cent of ammonia.

191. The composition of guano has been studied by experienced chemists, both on the continent and in this country. The most complete analyses which have been published, are those of Mr. Denham Smith, communicated to the Chemical Society. The following is the composition of a sample of Peruvian guano, said to be of very superior quality; 100 parts contained—

Water	21·510
Organic matter and combined water	12·296
Potash	1·144
Soda	3·430
Ammonia	5·434
Lime	15·356
Magnesia	0·764
Muriatic acid	2·414
Sulphuric acid	2·106
Oxalic acid	12·850
Phosphoric acid	16·328
Uric acid	2·308
Humus	2·060
Sand	1·648
Loss	·352
	100·000

The above analysis is interesting, as exhibiting the true composition, and very complex nature of this curious deposit; but it is obvious, that for agricultural purposes, a different kind of analysis is required, in which the amount of the various substances, which give this manure its peculiar value, may be clearly understood by the farmer. Accordingly, in estimating the value of a sample of guano, the method which is followed in the laboratory of the Chemico-Agricultural Society, is to furnish the farmer with a clear statement of the per centage of water, organic matters, with the amount of ammonia which they are capable of yielding by decomposition; phosphates of lime and magnesia, and substances like common salt (chloride of sodium) and gypsum, which, though valuable for the food of plants, can be more economically supplied in other ways.

192. The following table exhibits the composition of four samples of guano lately sold in Belfast, 100 parts of each sample contained respectively:—

	I. Peruvian.	II. Ichaboe.	III. Ichaboe.	IV. Patagonian.
Water	13·00	29·20	20·68	29·40
Organic matters & ammoniacal salts	52·32	34·00	39·12	15·44
Alkaline sulphates & common salt, &c.	4·67 2·49	8·10	12·20	5·28
Phosphates of Lime and Magnesia ...	25·72	27·70	25·52	41·04
Gypsum	——	——	——	1·06
Carbonate of Lime	——	——	——	4·34
Sand and earthy matter	1·80	1·00	2·48	3·44
	100·00	100·00	100·00	100·00
The organic matters and ammoniacal salts, were capable of yielding of Ammonia	13·01	8·05	10·84	2·5

193. The value of guano, as manure, depends chiefly upon the compounds of nitrogen, and the phosphates which it contains; the alkalies and other ingredients of plants are usually present in too small quantity to exercise any decided effects upon vegetation; hence the judicious farmer, who is desirous of keeping his fields in proper condition, should add to it the ashes of sea-weeds (*kelp*) or common salt, to supply the materials in which it is deficient. A well-known English agriculturist, the Rev. Mr. Huxtable, states, that he has found that the most profitable way of using guano is, some weeks before sowing, to mix each cwt. of it with 1 cwt. of salt and 1 cwt. of gypsum. For the reasons just stated, it has been found better to manure with a mixture of yard dung and guano than with guano alone; and careful experiments made in Scotland have shown that these manures, mixed in the proportion of 10 to 14 tons of dung to 3 to 5 cwt. of guano, will raise a larger crop in the first instance, than from 30 to 40 tons of dung alone, and leave the land in as good, if not better condition, for the aftercrops, at about one-half the expense of the dung." The wholesale price of Peruvian guano in Liverpool is at present £9 9*s.* per ton. It is usually applied at the rate of from 3 to 5 cwt. to the statute acre, and to prevent the seeds being injured, it should, previous to sowing, be mixed with dry soil, peat mould, or with salt and gypsum, as above described. When guano was first introduced into this country, the farmers, who had been accustomed to regard bulk as necessary to a good manure, applied it in such large quantities that the crops were in many cases destroyed.

With regard to the permanency of guano, considerable apprehensions were at first entertained, but experience has shown that its beneficial effects upon the crops are not confined to a single season.

194. *Adulteration of Guano.*—The character of guano, as manure, has suffered severely from the tricks of an unprincipled class of manure manufacturers, by whom it is frequently so skilfully adulterated as to render detection impossible without scientific examination. It might be expected that I would give some directions to enable farmers to discover these adulterations, but I do not think that the chemical analyses of soils or manures can properly be performed by the farmer. In every case the purchaser of guano should

insist upon being supplied with an analysis, such as above given, in which the amount of phosphates and ammoniacal compounds, with the quantity of ammonia which they are capable of yielding by decomposition, is clearly stated. These are the substances which it would cost the farmer most to purchase in the manure market, and their amount in a sample of guano, may be taken as representing its actual value.

195. *Bones.*—At the present time bones are even more extensively employed than guano for manuring. Their reputation has progressed with the extension of the turnip husbandry, and their use has, in no small degree, contributed to improve the agriculture of districts which, from being inaccessible to the more bulky manures, were formerly regarded as hopelessly barren.

196. For many years, *crushed* bones have been regarded by the English farmer as his most valuable fertilizer; and by their application alone, the fields of Cheshire, and other counties, exhausted by producing substances rich in phosphates, as milk and cheese (54), had their ancient fertility restored. In both England and Scotland, their importance is at present very generally acknowledged. It is stated by a well-informed authority, that one-third of the whole turnip-crop of these countries depends upon them. In Ireland, though within the last two or three years, there has been a considerable extension of their use among the more intelligent farmers, yet a large bulk of the bones collected in this country are purchased by the Scottish farmer; and thus our fields are exhausted, not only by the cattle which are fed upon them for the English market, but by the loss of the compounds of phosphorus, which the crushed bones that we export contain.

197. *Composition of Bones.*—Like the plants upon which the animal feeds, and from which, it is evident, all the materials for its growth must have been derived, bones consist of two parts—a part which disappears into the air when they are exposed to a strong heat, in the open fire, and an incombustible ash which remains. In the plant, the combustible or *organic* part, constitutes by far the largest portion of its bulk. The ash left by burning a hundred weight of turnips would weigh only about three-fourths of a pound; but when bones are burned, the ash weighs more than the combustible matter which disappears. Bones differ in density, and in the

amount of combustible matter which they contain, according to the age of the animal, and other circumstances. A bushel usually weighs from 42 lbs. to 45 lbs. Fresh bones, as applied to the land, contain about twenty per cent of water. The following is their per-centage composition, when dry:—

Organic combustible matters,	$33\frac{1}{4}$ lbs.
Incombustible matter or ash, consisting of	
Phosphate of lime (bone earth),	$55\frac{1}{2}$
Phosphate of magnesia,	3
Carbonate of lime,	$3\frac{3}{4}$
Salts of Soda,	$3\frac{1}{2}$
Fluoride of calcium,	1
	100 lbs.

198. The organic portion of bones consists of oil, and of a jelly-like matter possessing nearly the same composition as horn, skin, and hair. This matter is capable, by its slow decay in the soil, of producing two gases—carbonic acid and ammonia—by means of which, it is considered, that carbon, which we recognise as the chief constituent of wood, starch, &c. (60–64) and, also, nitrogen, the element so indispensable to the formation of the seed, may be supplied to the rootlets of the growing vegetable, and employed for its development. The organic matter of 100 lbs. of bones is capable of yielding about $5\frac{1}{4}$ lbs. of nitrogen. The earthy matter consists chiefly of the phosphates which, as I have repeatedly explained, are of such immense importance to our soils.

199. *How do Bones act?*—The mode in which bones prove serviceable is yet an unsettled question among scientific agriculturists. Formerly, before chemistry had demonstrated the importance of the inorganic elements of plants, it was generally supposed that all their qualities, as fertilizers, were due to the organic matter which they contained. This opinion, however, was considerably shaken by the observations of many farmers, who had employed burnt bones, and the bones which are boiled at Manchester for the manufacture of glue, apparently with equal, and, in some cases, it is reported, with superior effects to those produced by crushed bones. At present, many persons are inclined to attribute all the effects produced to the phosphates which they supply to the exhausted soil. Sprengel, who is a supporter of this opinion, instances their failure in places in the north of Germany, where other animal manures, rich in organic matter, had

with advantage been applied, and maintains, that it depended upon the soil being already supplied with compounds of phosphorus. Professor Johnston, who is among the most earnest advocates for the fertilizing virtues of the organic matter of bones, does not accept Sprengel's explanations of the failure of bones in Northern Germany, but argues, that it arises from the undrained state of the land to which they were applied. There can be no doubt that the *organic* matter of bones, as theory would lead us to suppose, possesses valuable qualities as a manure. The liquid which is extracted by boiling bones, in the dyeing manufactories of Manchester, even after it has been deprived of so much of its size as to be considered unfit for stiffening, is found to promote vegetation, and is eagerly purchased by the farmers of Lancashire and Cheshire. Burnt and boiled bones have been found to commence their action sooner than those unburned; but this cannot be regarded as a proof that the organic portion is of no value, but merely shows, that the fat and gelatine may retard the progress of decay, and the action of the gases, by which the insoluble phosphates are rendered fit for being taken up by plants. Again, the observations frequently made by experienced practical farmers, in England that twenty stones of horse-hair, which are considered to contain organic matter equivalent to that of sixteen bushels of bones, will not produce an equal effect upon the soil, may also be regarded as a proof, that, to the phosphates, bones owe a large share of their useful qualities. We may fairly assume, that the effects which burnt or unburnt bones produce upon a soil will, like the effects of all special manures, be materially affected by chemical composition. When a field contains a sufficient supply of organic matter, and is deficient in phosphates, burnt bones may produce the most immediate and decided effects; while, upon a soil which has become poor in decomposing vegetable matter, the crushed bones will be found the best application. Though there are few soils in Ireland that would not be greatly benefited by the use of burnt bones alone, yet I would not advise our farmers to prepare them in that form, or to destroy matters which we know contain ingredients of great value. From what has been stated of the fertilizing qualities of the size liquid, and also of the ash or bone earth, we may, I think, conclude, that both of these substances, as their composition would lead us to suppose, are capable of contributing to the growth of plants; and, in the present state of our knowledge, and before we are warranted by experiments made on the soils—not of Germany, England, or Scotland, but of those formed from our Irish rocks, and under the influence of our Irish climate—I would, I repeat, not advise the farmer to follow the opinion of those who would direct him to burn bones before applying them to his fields. It would, I conceive, be almost as judicious for him to burn Patagonian guano, to procure the phosphates which give that substance its chief value. (185)

200. *To what crops should bones be applied?*—Popular opinion, and the practice of the most experienced farmers, have pointed them out as *specially* adapted for the turnip-crop. Like guano (191), bones contain all the ingredients which plants require for their growth; but their analysis (197) shows us that some of the inorganic matters are not present in sufficient quantity to render it safe for the farmer to rely upon them as the only manure for his fields for a number of years. When the soil is deficient in alkalies, if you grow upon it a crop of turnips, 20 tons of which, in the tops and bulbs, carry away so much as $265\frac{1}{2}$ lbs. of potash and soda, its fertility will be seriously impaired, if no other manure than bones be used; hence it is advisable that the farmer should combine with them farm-yard dung, common salt, kelp, or some other manure capable of supplying these substances.

201. *What is the difference in the action of bones and guano?*—This is a frequent question. Like bones, guano can be separated, by burning, into two parts—an organic combustible portion, which is consumed, and a fixed, incombustible ash. This ash usually contains the same ingredients that we discover in bone earth; but, in the different kinds of guano, they are found in very unlike proportions. The proportions of organic matter and ash also differ very much in the different varieties of that substance which are brought to this country: thus, in the genuine Peruvian, the organic matters, capable of yielding ammonia, range from 50 to 60 per cent, and the phosphates of lime and magnesia average about 26 per cent; while in the Patagonian, and some other varieties, the relative proportion of these substances is very different, and approximates them to bones in their composition. But

equal weights of crushed bones and good Patagonian guano, applied to the same field, do not, it has been found, produce an equal return.

202. The experience of farmers shows, that, *weight for weight*, the guano, especially on dry and sandy soils, is capable of yielding larger crops. This superiority of guano is to be explained, first, by the fine state of division in which its constituents are presented to the soil; and, in the second place, by the readiness with which its organic matters yield up their ammonia. Bones cannot, without difficulty, be reduced to a coarse powder, except by the assistance of powerful and expensive machinery. Placed in the soil in a coarse state, they decay but slowly; and many years must elapse before all their ingredients are converted into a form in which they can produce their effects upon the crops of the farmer. The farmers, in some parts of Scotland, are accustomed to apply them broken into half-inch and three-quarter inch pieces; but in this state their application will not be productive of the immediate results which are observed when they are applied in a more minutely divided state, and which, especially for the turnip-crop, it is most important to produce.

203. In England, various plans have been adopted to secure their more ready decomposition. Some persons place them in a heap, covered over with earth, and allow them to heat and ferment, by which means their decomposition, when placed in the soil, is considerably accelerated; others, again, mix them with farm-yard manure, and leave them to ferment. Both plans are useful; but to chemistry the practical farmer is indebted for another mode of effecting their division, which far surpasses any method hitherto attempted, and which has, during the last two or three years, been extensively adopted, with the most signal success,—I allude to the decomposition of bones by the action of sulphuric acid (vitriol), or of muriatic acid (spirits of salts). By means of these cheap and well-known acids, it has been found, that they can be converted into the most effective and economical form in which they can be given to the soil. For this valuable method, the English agriculturist is indebted to that great man, whose writings have done so much to direct public attention, in this country, to the services which science is capable of rendering to the farmer. In his report on the

chemistry of agriculture, Baron Liebig says, that "the most easy and practical method of effecting the division of bones, is to pour over them half their weight of sulphuric acid, diluted with three or four parts of water, and after they have been digested for some time, to add about one hundred parts of water, and to sprinkle the mixture before the plough. In a few seconds, the free acids unite with the bases contained in the earth, and a neutral salt is formed, in a state of very fine division. Experiments, instituted on a soil formed from Grauwacke (126), for the purpose of ascertaining the action of the manure thus prepared, have distinctly shown, that neither corn nor kitchen plants suffer injurious effects in consequence, but that, on the contrary, they thrive with much vigour."

204. The difficulty of applying liquid manure, which requires water-carts, and arrangements not generally accessible to farmers, suggested other methods of applying "dissolved bones," which are now usually adopted. It has been found, that by drying up the liquid mixture, by the addition of dry peat-mould, by sawdust, or even by vegetable earth, it could be converted into a form in which it might be more conveniently used by the majority of farmers.

205. The chemical changes produced upon bones by the action of sulphuric acid, which is the acid now usually employed, are very important. When the diluted acid is poured upon the bones, there is at first a violent frothing up or effervescence, such as we observe when we pour vitriol upon pieces of limestone. This effervescence is produced by the rapid disengagement of carbonic acid, which is a constituent of both limestone and bones; and, in both cases, the same compound, sulphate of lime, or, as it is commonly termed, *gypsum*, is produced. But bones, as the analysis shows, in addition to the compound of carbonic acid and lime, which is one of their ingredients, also contain a large amount (58½ per cent) of the insoluble phosphates. The sulphuric acid also unites with a portion of the lime, in these compounds; while the excess of the compound of phosphorus (phosphoric acid) which is separated, unites with the remainder of the lime, to produce a new compound, which, from containing a larger amount of phosphorus than the original phosphates, is termed *super-phosphate of lime*. This new phosphate is soluble in water, and is, therefore, capable

of at once ministering to the growth of plants. The organic matters of the bones also undergo decomposition, and are converted into new forms. Thus, by the influence of this acid, the fertilizing qualities of bones can be rendered immediately available, and the chief objection to their use removed.

206. There are various names given to this preparation of bones, which occasionally create confusion, as *dissolved bones, sulphated bones, super-phosphate of lime, vitriolized bones.* Of these names the last is, probably, to be preferred, as it at once expresses the ingredients of the compound. The extended use of this valuable manure, at the present time, requires that I should make a few remarks on the plan to be followed, in its preparation by the farmer. Various methods are adopted; but the following can be recommended:—

I. *How the bones should be prepared.*—The bones to be used cannot be broken too small; the more extensive the surface presented to the action of the acid, the more rapid and perfect will be the solution. The bones usually employed are in too large pieces; and a higher price should willingly be given for them when reduced to powder. The price of half-inch bones, as they are termed, is in Belfast 2*s.* 6*d.* per bushel. In every farm-yard, an old sugar hogshead should be kept, into which all the bones, woollen rags, old hats, and broken leather, should be thrown, and preserved, for being reduced to manure in the vitriol vat.

II. *Quantity of vitriol to be used.*—The acid should be purchased of full strength; that is, of the specific gravity at which it is sent from the manufactory, *viz.* 1·845. It should be kept in a close vessel, as, when exposed, it rapidly attracts moisture from the air, and becomes weaker. It must not be forgotten, that it will burn both the skin and clothes, if allowed to come into contact with them. When the strong acid is mixed with water, a considerable amount of heat is produced: twenty-five pounds of oil of vitriol, mixed with ten pounds of water, will raise the temperature to 266 degrees. The proportion of acid to be used in the preparation of vitriolized bones, is one hundred weight of acid for every two hundred weight of bones to be dissolved. A smaller amount of acid is frequently applied; but the above proportions will give the most satisfactory results. Vitriol, of full strength, can be purchased from the manufacturer at 1*d.* per pound.

III. *Quantity of water, and mode of applying it.*—When undiluted vitriol is poured upon bones, violent action is produced, but continues for a very short time, as the gypsum, which is the first new compound formed, covers the surface of the pieces of bone with a crust, which prevents the acid from coming into contact with the unaltered portions, and, in consequence, its action is retarded, and a perfect solution is not procured. If you drop some concentrated vitriol upon a piece of limestone, there is a bubbling up, or effervescence, from the escape of carbonic acid gas, but it continues only for an instant. A crust of gypsum forms and protects the stone from the acid; but, if you use vitriol diluted with water, the action and escape of gas continue for a much longer time. The best plan, therefore, is to thoroughly moisten the bones you intend to dissolve, by pouring over them a quantity of water, and allowing them to soak in it for an hour or two before adding the acid. The quantity of water used should be three or four times that of the vitriol to be employed. This mode of applying the water obviates the trouble of mixing together the vitriol and water in a separate vessel, as some recommend, and the heat generated, by adding the strong acid to the moistened bones, greatly facilitates the decomposition, and hastens the preparation of the compound.

207. *Animal substances occasionally employed as Manures.*—In addition to bones and guano, there are several animal substances used as manures in England and on the continent, but which are seldom or only casually applied by the Irish farmer. Of these substances, therefore, only a brief account will be necessary. *Fish and shell-fish* have long been considered most valuable fertilizers. It is, indeed, complained, that unless made into a compost with soil, they prove *too strong* for the land. On the east coast of Scotland, Stephens, in *The Book of the Farm*, informs us that, in the fishing villages, where the fish are smoked or salted, the refuse is purchased by the farmers, and constitutes an efficient manure for every kind of crop. "Thirty barrels of fish heads and guts, half of cod and half of haddock, are," he states, "enough of manure for one acre. The barrel contains thirty gallons, and four make a cart-load. The refuse sells at 1*s.* 6*d.* per barrel. In preparing fish refuse for manure, it is emptied from the barrels on a head-ridge of the field to be manured, and mixed with a quantity of earth, sufficient to

cover the refuse completely. It is driven fresh to the field, whenever a supply can be obtained from the fishers. In two or three months the compost is ready for use, and, as a manure for turnips, is superior to farm-yard dung, and equally beneficial on light and heavy soils. When used for turnips, the compost is spread with shovels, out of the cart, along the drills, at the rate mentioned, over which the drills are split, and the seed sown along the drills by the machine. Of course, it may be applied to bare fallow, for wheat as well as for green crops." On the coasts of Ireland, we possess numerous deposits of muscles, and other varieties of shell-fish, which could be conveniently applied as manure. On the shores of Strangford Lough, there are immense accumulations of vegetable matters and mud, full of shells, which might, with very little expense, be carted over the fields, but which, so far as I am aware, have not yet been economized by the farmer. In Donegal also, at Mulroy Bay, and in several other localities, there exist beds of shell-sand, which are, at the present time, extensively used as manure.

208. *The flesh of animals, and blood*, which may be regarded as liquid flesh, are not, to any extent, used as manures in this country. Originally derived from plants, both contain the most valuable ingredients of the soil, and are also rich in nitrogen. In Paris, the blood from the slaughter-houses is carefully collected and dried, and, in that state, sold at 8*s.* per cwt. Recent flesh and liquid blood possess the following composition:—

	Flesh.	Blood.
Water	77	80
Organic matters	22	19
Phosphate of lime	$\frac{2}{3}$	1
Other saline matters	$\frac{1}{3}$	
	100	100

209. The inorganic matter, or ash, of the blood of the ox, according to Dr. Enderlin, contains the following ingredients of plants:—

Phosphate of Soda	16·77
Common Salt	59·34
Chloride of Potassium	6·12
Sulphate of Soda (Glauber Salt)	3·85
Phosphates of Lime and Magnesia	4·19
Oxide and Phosphate of Iron	8·28
Gypsum and Loss	1·45
	100

Blood decomposes with facility, and is, therefore, a good addition to the compost heap, as it induces the decomposition of other substances.

210. *The parings of the skins of animals, and horn shavings*, contain a larger amount of nitrogen than blood or flesh; skin leaves, when burned, only $\frac{1}{2}$ per cent, and horn about $\frac{7}{10}$ per cent of ash. In the neighbourhood of tan-yards, where they can be procured, these substances are used with great advantage; but at present, they are chiefly consumed in the manufacture of glue. Horn shavings decompose slowly in the soil; therefore, where an immediate effect is required, they should be either made into a compost, or dissolved in the vitriol vat with the bone manure.

211. *Woollen rags and hair*.—The first of these substances is very extensively used in England, especially in the hop-growing districts; 20,000 tons being, it is said, annually applied to the soil by the farmers in Kent, Sussex, Oxford, and Berkshire. Rags are also occasionally used for wheat and potatoes, and are considered to be most efficacious on the light chalk soils. They are cut into pieces with an instrument like a turnip-cutter, and are spread by hand over the land, at the rate of 12 or 15 cwt. per acre. They decompose slowly on the soil, and should therefore be either ploughed in a considerable time previous to putting in the seed, or made into a compost. They are sold at from £3 12*s*. to £5 per ton. Both rags and hair are poor in inorganic matter, but contain a larger amount of nitrogen than blood or flesh. Like bones, they consist of an organic or combustible matter, and an incombustible ash.

In China, hair is considered one of the best manures; but in this country it is seldom that it can be procured in sufficient quantities. Occasionally, it can be purchased at the tan-yards at from £4 10*s*. to £5 per ton. As met with in Belfast, it is usually mixed with about the fourth of its weight of lime.

212. *The refuse of the glue manufacture*, technically termed "gumps," is occasionally used as a manure in certain localities. It is a variable mixture of animal matters—hair, bones, lime, bone earth, and sand. This refuse is sold in two states,—as a moist mass, and in dry, brick-shaped lumps of a dirty white colour. The following is the composition of two samples of glue refuse, from the manufactory of Mr.

Tucker of Belfast, which were lately analyzed in my Laboratory. 100 parts of each contained as follows:—

	Dry refuse.	Refuse as taken from the boilers.
Water, ...	13·6	37·0
Organic matters, hair, &c.	28·5	30·0
Gypsum and traces of alkalies,...	2·2	
Carbonate of Lime, ...	42·1	28·4
Carbonate of Magnesia, ...	1·2	
Phosphate of Lime (bone earth),	2·4	1·6
Sand, ...	10·0	3·0
	100·0	100·0

The dry refuse, I found, would be capable of yielding two parts, and the fresh "gumps" seven parts of ammonia. The moist refuse should therefore be preferred by the farmer, and would prove a useful manure; as, besides the amount of ammonia which it would be capable of affording by its decomposition, a ton weight of it would convey to the soil about 36 lbs. of phosphate of lime (53). It must, however, be expected to vary very much in composition, so that the actual value of any sample can only be determined by analysis. The moist refuse is sold in Belfast at 12*s.* 6*d.* per ton.

CHAPTER IX.

MEANS ADOPTED FOR IMPROVING THE SOIL AND MAINTAINING ITS FERTILITY BY THE APPLICATION OF MANURES.

VEGETABLE AND MINERAL MANURES.

213. *Vegetable Manures.*—The animal manures which have been described in the preceding chapter, you have seen derive their valuable qualities from containing certain compounds which, by their decay, are capable of affording ammonia (154), and also the various inorganic materials which are equally indispensable for the nourishment of our crops. Therefore, by placing these manures in the soil, we restore to it the matters taken away in the course of cultivation. When we apply to our fields the decomposing straw, leaves, and other vegetable remains of the manure heap, we in the same way replace in the soil, the ingredients which the stems and leaves of our crops had appropriated during their growth.

214. *Green manuring.*—But in addition to employing animal excrements, and the decomposing litter and refuse vegetable matters collected in the manure heap, the farmers in various parts of Europe have been accustomed from the earliest times to enrich their poor or exhausted soils, by growing upon them certain crops, which instead of being used for food, are ploughed in to serve as manure. This practice of *green manuring*, as it is termed, is regarded as signally beneficial in the countries in which it is practised; thus the farmers in the north of Germany find that the most effectual method of obtaining good crops of rye from sterile sandy soils is to manure them with several crops of spurrey or of white lupins, and in the United States, both clover and Indian corn are frequently ploughed in for the purpose of enriching the land. In some parts of England and Scotland, buck-wheat and vetches are grown as manure-crops, and turnips are also occasionally ploughed in spring as a preparation for wheat.

215. When green vegetables are buried in the soil, they undergo the same changes as when placed in the manure heap; they are rapidly resolved into their original elements, and yield up the mineral matters and gases which they had accumulated

during their growth, and thus "the destruction of an existing generation becomes the means for the production of a new one; death becomes the source of life."

216. If you recollect that the great bulk of every plant is derived from the air, you will readily understand, that by burying in the soil the crops produced upon it, you will not merely restore the matters which they had abstracted during their growth, but increase its natural fertility by adding to it the elements which they had appropriated from the inexhaustible storehouse of the atmosphere. The plants selected for the purpose of being ploughed in are such as draw largely upon the air for their nourishment, and which can be made at little expense, in a short time, to produce a large crop of leaves and stems. It is usual to turn them into the soil just before the period of flowering, as at that time they are found to contain the largest amount of useful matters. But besides increasing the amount of organic matter in poor soils, much of the beneficial effects of green manuring is to be attributed to the mineral matters contained in the decaying plants. Thus, when a crop of grass is ploughed down, the inorganic matters which the deeply penetrating roots had extracted from the subsoil, are transferred to the comparatively exhausted surface, and brought within the reach of the succeeding crop. In Ireland, though crops are rarely cultivated with the design of being used as manure, yet the application of various kinds of vegetable matter to the soil, is among the most important means employed to maintain its fertility; thus the sea-weeds or *wrack*, which are found in so great abundance on our coasts, and the deposits of vegetable matter in our bogs, are used in every part of the country where they can be obtained.

217. *Sea-weeds.*—These plants have long been employed by the farmers on the coasts of France, Scotland, and Ireland; and as analysis shows that they contain all the ingredients which our crops require, they must be capable of contributing to the fertility of any description of soil. In many districts in Ireland, no other manure than "sea-wrack" is applied, and by its assistance the land is enabled, year after year, to produce the most exhausting crops. Sea-weeds are frequently employed for dressing meadow lands, and are found greatly to improve the quality of the grass; they are also formed into composts with farm-yard manure, and, as they contain a considerable amount of nitrogen, they rapidly ferment, and

as usually allowed to remain for months exposed to the weather, must lose much of their valuable qualities. By adopting the precautions which I described as necessary, in the management of farm-yard dung, much of this loss may be prevented. The fresh weeds are also frequently placed in the drills with the potato sets, and, thus used, produce a most abundant crop, though the potatoes are said to be more *waxy* than those grown on farm dung. It is necessary to prevent the sets coming into immediate contact with the weeds, as they are said to be injured when placed upon it; applied to cabbages, they are found greatly to improve their flavour. The fresh weeds are usually employed at the rate of 30 tons to the statute acre.

218. *Composition of sea-weeds.*—As taken from the sea or cut from the rocks, sea-weeds contain a very large amount of water; the leaves (*frond*) of the bladder-wrack, and the stalks and leaves of the tangle, which are highly valued by the farmers on our coasts, contain in the 100 parts respectively as follows:—

	Water.	Organic combustible matter.	Ash.
Bladder-wrack, ...	68·8	26·20	5·0
Leaves of tangle, ...	81·1	13·10	5·8
Stalk of do.	84·0	10·40	5·6
Do. do.	83·1	11·06	5·8

A ton therefore of the above weeds, mixed together, would, when fresh, convey to the soil about 123 lbs. of mineral ingredients.

219. Formerly, enormous quantities of sea-weeds were burned on the coasts of Ireland and Scotland for the sake of the soda (44), which is one of the chief constituents of their ashes; but at present that alkali is procured from other sources, and only a limited amount of *kelp*, as the fused ashes are termed, is prepared for the use of the Iodine manufacturer (page 48, *note*). From several analyses of the kelp prepared on the north-east coast of Ireland, I was some time ago induced to recommend it to the attention of farmers, as a valuable and convenient source of the saline matters removed from our fields by cultivation, and especially for supplying the alkalies so essential to the growth of the potato

and turnip-crops. The following are the ingredients useful to plants, which 100 parts of Irish kelp contain*:—

Potash,	8·22
Soda,	25·82
Lime,	5·17
Magnesia,	8·47
Sulphuric acid,	20·17
Phosphoric acid,	5·43
Chlorine,	11·70
Silicic acid,	5·71

220. Kelp, therefore, presents us with a supply of some of the most important and expensive elements of plants, in a convenient and portable form, so that they can readily be carried into the interior of the country, where their action might be expected to prove more beneficial than near the coast, where sea-weeds are frequently applied to the land, and the rains, carried over the fields by the sea-breeze, deposit a certain amount of saline matters.

221. When sea-weeds are burned, to be used as manure, the ashes should not be fused into solid masses, as is usual in preparing kelp, as it is a very troublesome operation to reduce them to powder; the vegetable matter should be only half consumed, by which means the ashes will be obtained in a loose form, more convenient for distribution over the fields. Kelp is usually sold on the coasts of Ulster at from 30*s*. to £3 per ton.

222. *Peat.*—Among the numerous vegetable substances which this country affords, capable of being employed by the skilful farmer in maintaining the fertility of the soil, are the contents of our bogs.

There are three forms in which bog-stuff or peat is used as manure by experienced farmers. 1st,—Made into a compost with farm-yard manure. 2d,—Converted into a kind of charcoal, by being burned with a smothered fire. And 3d,—As consumed with free exposure to the air, and reduced to ashes. I will describe the methods adopted for its preparation in the above forms, and also their properties.

223. Peat earth, though from a very early period occasionally employed as a manure, was first brought into general

* The teacher will find some remarks on kelp as a manure, in a report which I addressed to the Chemico-Agricultural Society of Ulster, in May, 1846.

notice by the late Lord Meadowbank. It is well known, that in its natural state, it exhibits very little disposition to decompose, and is therefore not much esteemed as an addition to land. Lord Meadowbank, however, proposed to form it into a compost, by mixing it with hot fermenting farm-yard dung, by which means its indisposition to decay is overcome, and it is in a short time converted into a highly-fertilizing manure. He recommended, that one ton of strong fermenting farm-yard manure should be placed in alternate layers with two and a-half tons of dry peat mould. The value of this compost is now fully appreciated by some of the most experienced farmers in this country and Scotland.

224. When turf is required for manure, it should be raised from the bog in dry weather, and allowed to remain for a week or two exposed to the air. It may then be used to form the manure heap. The proper fermentation of the mass will be promoted by occasionally watering it with some liquid from the cow-house; or the dry mould, instead of being formed into a compost, in the manner advised by Lord Meadowbank, may be advantageously employed as a means of absorbing, or sucking up the various liquid manures, urine, &c.

225. Dr. Shier, in a note to his edition of "Davy's Agricultural Chemistry," states that he has repeatedly tried the following compost, and has found it to raise a better crop of turnips than an ordinary dose of farm-yard manure:—"Ten tons of half-dried peat that had been several times turned, and well exposed to the air, were mixed with six bushels of sifted bone dust, weighing 56 lbs. or 58 lbs. per bushel, and turned. At the next turning, the mass was mixed with 56 lbs of sulphate of ammonia, and as much nitrate of soda. After standing a few days, it was fit for use." The above mixture would yield a most valuable manure; but in many parts of Ireland, it would be impossible to procure either sulphate of ammonia or nitrate of soda. Farmers, however, who reside in the neighbourhood of large towns, may employ with great advantage the ammoniacal liquor of the gas works for moistening the heap, in the preparation of peat composts.

226. I have already recommended tanks for liquid manure, as essential to the economy of every well-regulated farm establishment. A simple manure tank, of the kind described,

could easily be procured by the small farmer; and in districts where peat abounds, would be found most useful, and enable him to prepare a supply of rich manure. A bed of the dry peat mould might be formed, and where a pump is not at hand, a bucketful or two of the contents of the tank could be used for moistening it, and by adding occasionally some fresh mould, a valuable compost would be produced, containing the most essential ingredients required for the nourishment of his crops.

227. Along the coast, where sea-weeds can be procured, they present us with an excellent substance for mixing with peat, to convert it into manure, as the weeds rapidly ferment, and communicate to the mould the tendency to decay.

228. *Peat Charcoal.*—When peat is burned with a smothered fire, it is converted into a light and friable charcoal, which has been found to possess a high value, not only as a fertilizer, but for the manufacture of gunpowder, and the various industrial purposes for which wood charcoal is usually employed. When it is remembered, that nearly one-seventh of the entire surface of Ireland is covered with bogs, the consideration of the various plans proposed for converting their contents into a more valuable form, becomes of great importance.

229. *Preparation of peat charcoal.*—For this purpose the following simple directions have been given by Mr. Rogers, who has devoted much attention to the subject:—If practicable, have the turf of a good, hard kind, and as dry as possible. Let it be piled in a circular, conical shape, something like a hand-cock of hay, about from three to five feet across at the bottom. Place all the first layer of sods standing on their ends, and resting against each other, in the shape of an A; and let the second layer lie against the back of the first, continuing each layer in that manner up to the top, filling in between with sods placed on their ends upright: by this means the air will be admitted freely through the whole, and produce combustion throughout. Set it on fire, by straw underneath, and after a short time the entire heap will become a red mass. When in this state, *and not till then*, it is to be extinguished perfectly. This may be done by a moderate portion of water, if the charcoal be for manure; but even in that case it should only be just sufficient to extinguish it. It may also be *smothered*, either by means of a

tarpaulin dipped in water, or by damp sods, or scraws, placed over the whole, so as to *perfectly exclude the air*. This must be done effectually, or it will continue to burn; and a very certain way to do this is, to throw round it at the base, after the tarpaulin or scraws have been placed over the whole heap, a few shovelfuls of clay, so as to prevent any air from entering underneath. When charcoal is to be prepared on a large scale for extensive farms, an *extinguisher* made of sheet iron, sufficiently large to cover the heap and rest close in the ground, will be desirable; and can be made at a trifling cost. Two handles, extending about a yard at each side, in the form of a T, will enable it to be lifted, and placed over the heap, without inconvenience from the heat, &c. When the heap of charcoal has become cold, the lumps may be broken up by mallets or pounders, with very little labour, and, for general purposes, should be about the same size as coarse sand.

230. Having described the preparation of peat charcoal, and the valuable fertilizing qualities which it has been found to possess, I will now endeavour to reply to the inquiry which has several times been addressed to me by persons desirous of applying it as a manure:—*Is it, by itself, to be regarded as a sufficient manure for all the crops of the farmer?* Trials, made both in this country and on the continent, have shown, that, drilled in with wheat, it has tended greatly to promote the growth of that grain. It has also been used alone, with success, as a manure for the turnip and potato crops; but I do not consider that it could be judicious to advise you to rely upon it as sufficient, in all cases, to ensure a full return. Such advice might lead to disappointment, and induce you to neglect what I regard as a really important addition to our stock of home manure.

231. It should be regarded by the farmer not as a universal medicine, capable of curing all the diseases of a neglected and worn-out field, but as a useful auxiliary, which, when combined with kelp, dissolved bones, or saturated with the fertilizing liquids, at present permitted to run away from his stables and cow-houses, will give him a cheap and valuable compound, containing everything that his crops require for their full development, and which may be relied on with confidence—mixed, as I lately described, with ordinary farm-yard dung, it will also be found to contribute, in no small

degree, to its value (184), by retaining matters which, as that manure is usually managed, are lost to the farmer.

232. *Inorganic matters contained in peat.*—In an examination, lately made of this manure, as it is usually prepared by skilful farmers in Scotland, it was found that every hundred pounds of peat charcoal, placed on a field, would convey to it the following ingredients. The proportion of ashes will, of course, vary, according to the extent to which the air is allowed to penetrate to the heap, in burning the peat, and their composition will also be different, in various samples.

Charcoal,	54·12
Sulphates of Potash, Soda, and Magnesia,	6·57
Alumina,	2·99
Oxide of Iron,	4·61
Sulphate of Lime (gypsum),	10·49
Carbonate of do	8·54
Phosphate of do	0·90
Siliceous matter,	10·88
	99·10

The above mixture affords the very materials which every plant that is grown must procure, to form its leaves, its stalk, and its seeds.

233. The amount of phosphate of lime in charred peat is, however, not sufficient to induce the farmer to rely upon it as his only manure, for a number of years; and it will be advisable for him to apply with it some of the fertilizers above described.*

* I was lately favoured by J. J. Burnett, Esq. Glenarm, with a statement of the results of some experiments made by him at Gadgirth, in Ayrshire, with mixtures of charcoal, kelp, and other manures, which are exceedingly interesting.

Experiments with various manures.—Crop, Swede turnips.

Applied per Scotch acre.	Weight per Scotch acre.
No. 1. 20 tons of farm manure, 1 cwt. African guano, 1 cwt. charcoal (wood),	28 tons 10 cwt.
No. 2. 20 tons farm manure, 2 cwt. Peruvian guano, 1 cwt. wood charcoal,	31 tons.
No. 3. 20 tons farm manure, 1 cwt. African guano, 8 bushels ground kelp, 2 cwt. salt,	33 tons 10 cwt.
No. 4. 20 tons farm manure, 4 cwt. concentrated manure,	31 tons.

234. *Rape-dust.*—As the most valuable portions of the organic and inorganic matters of vegetables are accumulated in the seeds, their application to the soil, when their power of germinating has been destroyed, must prove exceedingly useful. In Italy, the seeds of the white lupin, and in England, the cake (77) which remains when the linseed, rape, and other oily seeds are subjected to pressure for the preparation of the oil, are much employed as manure. The cake contains all the nitrogen and inorganic matters of the seeds, and must therefore possess great activity as manure. It is usually crushed into dust, and applied in that form. In many parts of England rape-dust is regarded as especially beneficial in promoting the growth of grain, and particularly upon thin, poor soils, deficient in organic matter. Its effects are rapidly produced, but are not of long continuance. Combined with more lasting manures, it has been found of great value in starting the turnip-crop. The most economical and certain method of applying it, according to Mr. Hannam, is by drilling it in with the seed; and, in using it, care should be taken, as with all rapidly fermenting manures, to mix it with a little earth, so as to prevent its coming into immediate contact with the seed (193). In Belgium, the farmers mix both rape and linseed-cake with their liquid manure, to

The soil was a medium clay, with a hard subsoil, but was thorough-drained and subsoiled. Lot No. 3 was the best in appearance the whole season, although the worst part of the field, as to soil; and the turnips on this lot were more solid and firm in texture. The crop was sown on the 10th June, 1844, and weighed in February, 1845.

The concentrated manure, of which the following is an analysis, by Professor Penny of Glasgow, cost 4*s*. per cwt.

ANALYSIS OF CONCENTRATED MANURE.

Organic matter soluble in water	3·93
Salts of Ammonia	1·50
Salts of Potash and Soda	1·28
Organic Salts of Lime and Magnesia	8·40
Phosphate of Lime and Magnesia	5·30
Carbonate of Lime and Magnesia	1·30
Oxide of Iron	0·80
Animal matter, &c. insoluble in water	34·50
Silica, &c.	26·23
Water	15·00
Loss	1·76
	100·00

improve its qualities, and apply the mixture with great advantage to the flax-crop. In England, rape-dust is applied at the rate of from 8 to 16 bushels per acre, and is usually sold at about £7 per ton.

235. *The husk of the oat, malt-dust, and the bran of wheat*, may all be used with advantage as manures, and should be economized by the farmer. *Wheat bran*, especially, should be regarded as a valuable fertilizer, being rich in both nitrogen and saline matters. It has been used with remarkable effect in England.* Added to the manure heap, and properly preserved from excessive fermentation, all these vegetable substances will be found useful applications to the soil.

236. It may be useful for you to recollect, in considering the effects which the various animal and vegetable substances employed as manures, are capable of producing, that the *immediate* effects which may be expected to follow their application will depend *chiefly* upon the amount of matters capable, by their decomposition, of yielding ammonia, which they contain, while the *permanence* of their action will depend upon the amount of inorganic matters, and especially of the phosphates of lime and magnesia.

237. *Mineral and saline manures.*—Formerly it was imagined that the only substances capable of supplying food to plants were those derived from animals and vegetables; and though, in various parts of the world, lime, marl, gypsum, saltpetre, and other mineral and saline matters, dug out of the earth, had been used with extraordinary success in increasing the fertility of the soil, yet it was considered that these substances were not true manures, but merely in some unknown manner *stimulated* plants to consume larger quantities of the food supplied in the soil, and, in consequence, accelerated its exhaustion, "enriching the fathers while they impoverished the sons." The progress of agricultural chemistry has, however, given us more correct opinions with

* Professor Johnston gives the following as the average composition of the bran of wheat:—

Water	13·1
Albumen coagulated	19·3
Oil	4·7
Husk, and a little starch	55·6
Saline matter	7·3
	100·0

respect to the action of these substances, and has shown us that, like the inorganic matters contained in the ashes of sea-weeds and peat, and in the excrements of animals, they increase the produce of the soil, because they supply it with some of the materials indispensable to the growth of plants.

238. From the information which you have acquired, you will find no difficulty in understanding why the application of one kind of mineral or saline matter should occasionally disappoint the expectations of the farmer; why gypsum should promote the growth of the crops in one district, and produce no effect in another part of the country; or why lime or marl should, after a number of years, cease to insure a fertile return, and seem even to injure the land. You are aware that it is only in proportion as you place in the soil the materials taken away in cultivation that you can expect to maintain its productiveness; that lime or nitrate of soda, or saltpetre, will be sufficient to enable it to yield crops *only* when the eight or nine other substances which are discovered in the ashes of your crops are already present in sufficient quantities; and that if, year after year, you carry away in your crops several of these substances, and replace only one or two of them in the manures which you apply, exhaustion must sooner or later be expected to occur.

239. *Artificial manures.*—The striking effects which attended the use of guano and bones, which led the most sceptical to admit that bulk was not indispensable to the efficacy of manures; and the information which chemists communicated, that the materials from which these substances derived their fertilizing power were the same that existed in fertile soils, and in the ashes of plants, suggested the possibility of compounding mixtures adapted to the *special* wants of the various crops cultivated by the farmer; and within these few years so great has become the demand for these artificial compounds, that a new and important trade has been created in preparing them. In England and Scotland, at the present time, enormous quantities of mineral substances and chemical compounds are used as manures: of sulphuric acid alone, it is said that last year as much as 127,750 lbs. were consumed by the farmers in one agricultural district in Yorkshire.

240. I have already, in Chapter III. described to you the leading characters of the mineral and saline matters which are

discovered in the ashes of plants, and the table given at p. 99, will show you the proportions in which the crops that you cultivate require them for their growth. Though the success of the experiments which have been made with various saline compounds, both in England and Scotland, are most encouraging, yet in the present circumstances of the agriculture of this country, with rich stores of fertilizing materials accessible to every farmer, your attention should be directed rather to the economy of the natural supplies of these matters, which have lately been described, than to the preparations of the chemical manufacturer. The following table, however, will be found useful to those who possess the means, and are desirous of entering upon this new path, which the progress recently made in the study of the composition of the inorganic matter of plants, has opened up to the improving agriculturist.

Composition in 100 parts of the saline and mineral substances employed in the preparation of special manures.

	Carbonic Acid.	Nitric Acid.*	Sulphuric Acid.	Potash.	Soda.	Lime.	Magnesia.	Water.
Carbonate of Potash	31·43	..	..	68·57	..	..	..	..
Carbonate of Soda, dry	41·42	..	..	..	58·58	..	..	..
——— Crystallized	15·43	..	..	..	21·81	..	..	62·76
Sulphate of Soda *Glauber Salt*, dry	..	..	56·18	..	43·82	..	..	..
——— Crystallized	..	..	24·85	..	19·38	..	..	55·77
Nitrate of Potash Saltpetre	..	53·44	..	46·56	..	..	..	..
Nitrate of Soda *Cubic Nitre*	..	63·40	..	..	36·60	..	..	..
Carbonate of Lime	43·71	..	..	..	..	56·29	..	..
Sulphate of Do. *Gypsum*, Crystallized	..	..	46·31	..	..	32·90	..	20·79
——— Burned	..	..	58·47	..	..	41·53	..	..
Carbonate of Magnesia	51·69	..	..	..	..	..	48·31	..
Sulphate of Do. Epsom Salt	..	..	32·40	..	..	..	16·70	50·90

* *Nitric acid* is the "aquafortis" of the apothecary. It is a sour corrosive liquid, which, in combination with potash, forms the salt termed *nitrate* of potash, and with soda, *nitrate* of soda. It is itself not an elementary body like chlorine (51), but a compound of nitrogen and oxygen—14 lbs. of nitrogen and 40 lbs. of oxygen forming 54 lbs. of

241. *Use of lime as manure.*—When common limestone (*carbonate of lime*) is burned in the kiln, the carbonic acid, which forms so large a portion of its bulk (45), is expelled into the air, and it becomes a porous mass, and experiences an important alteration in its properties. As it exists in the mountains, it is, as you are aware, both tasteless and insoluble; but, by burning, it acquires a *caustic* taste, and is rendered slightly soluble in water. In the *burned* state, lime has, from a very early period, been employed as an application to the soil in every part of Europe, and in many parts of this country is consumed at the present time in enormous quantities. As the effects which lime is capable of producing upon the soil, are in general very little understood by the greater number of our farmers, it will be necessary for us carefully to consider the nature of its operation, and also the composition of the rocks from which it is procured.

242. When water is thrown upon *burned* or *quick* lime, it rapidly absorbs it, gives out so much heat as to char wood, and falls into pieces. When exposed to the air, it also attracts moisture, and crumbles to powder; in this state it is termed *slaked*, or slacked lime, and is found to have increased considerably in weight, a ton of *quicklime* being converted into about 25 cwt. of slaked lime. It also gradually attracts carbonic acid from the air, and returns to the state of carbonate, though even after a very long period portions of it remain caustic. In this state it is usually termed *mild* lime, though, when allowed to slake in the fields, only about one-half of it is found to have entered into combination with carbonic acid.*

nitric acid. It is formed in compost heaps during the decay of organic matters containing nitrogen, and produced in the atmosphere during thunder-storms. It is believed by many persons that its compounds exercise a powerful effect on the growth of plants, by supplying nitrogen.

* The teacher may allow his pupils to perform the following simple experiments:—

1. Let 25 grains of common *un*burned lime be weighed, and introduced into a glass containing about two teaspoonfuls of muriatic acid (*spirits of salts*), diluted with an equal quantity of water; a copious effervescence will be produced, and it will nearly all dissolve: *test* the gas which escapes, as directed at page 30. When the effervescence has ceased, pour off the liquid without disturbing the undissolved matter, which may be washed so as to remove all trace of the acid, by pouring water upon it and decanting; the sediment collected on a piece of blotting-

243. The following analyses will show you the composition of several varieties of limestone, employed for agricultural purposes in Ireland:—

	Carbonate of Lime.	Carbonate of Magnesia.	Phosphate of Lime.	Oxide of Iron and Alumina.	Silica and Insoluble Clay.	
Magheramorne, Antrim	98·63	0·38	0·10	0·08	0·45	H
Glendun, do.	95·03	0·55	0·18	2·00	1·20	H
Larne,* do.	71·66	2·67	?	9·42	14·61	H
Moira, Down......	96·80	0·76	0·12	0·40	0·55	H
Castle espie, do.	94·40	1·38	0·05	0·40	2·40	H
Holywood, do.	48·33	44·11	0·31	2·25	5·00	H
Brown's Hill, Carlow..............	95·00	—	—	—	4·50	Griffith
Dublin (*calp*)	68·00	—	—	9·5	18·00	Knox.
Clones, Monaghan	89·08	1·97	—	0·66	8·16	Jones.
Newton Gore......	65·10	1·40	—	0·66	32·85	do.
Belturbet, Cavan	98·00	1·28	—	0·30	0·42	do.
* Blue Lias Lime.						

The above analyses of limestone rocks from various parts of Ireland, will show you that they differ considerably in their composition, and that when burned, they will convey different quantities of lime to the soil. It is only lately that attention has been directed to the amount of phosphate of

paper, dried before the fire and weighed, will show the amount of earthy impurities which the specimen of limestone contained.

2. Take 100 grains of quicklime, pour water upon it as long as it drinks it up; observe the heat given out; collect and weigh the powder which it forms, and note the increase in weight produced. Drop some of the powder into some diluted muriatic acid; if the lime has been carefully burned, there should be no escape of gas.

3. Introduce the remainder of the powder, with two or three glassfuls of water, into a bottle; cork the bottle, and shake the mixture; allow the undissolved part to settle down, and pour off the clear liquid, which is *lime-water*, and preserve it for experiment in a well corked vial. *Test* the lime-water, and you will find it alkaline (12). Blow air into it through a glass tube or straw, and it will become muddy from the formation of *carbonate* of lime, carbonic acid being contained in the air from the lungs (26).

lime, which, as all the analyses made in my laboratory show, our limestone rocks, like those which have been examined in England, contain. The amount of this valuable ingredient, as well as the other inorganic matters present, must exercise a considerable influence upon the effects which they produce.

244. Lime, when applied to the soil, produces changes both in its texture and chemical composition, of great importance to the farmer. Thus, it renders the stiff clays loose and porous; and the numerous beds of limestone gravel, derived from the crumbling down of limestone rocks, which exist in many parts of Ireland, and are so frequently found beneath the bogs, afford the farmer the very means required for consolidating and improving the qualities of the surface. There are, indeed, no soils in this country that would not be materially benefited by the judicious application of this valuable substance.

245. *How it adds to the fertility of the soil.*—You have seen that there is no plant which you cultivate that does not require a considerable proportion of lime for its food; it must therefore be an essential ingredient of every productive soil; and as year after year it is carried away in your crops, it must occasionally be applied. Upon soils formed by the crumbling down of the clay-slate and granite rocks, its frequent application is necessary, and to the farmers in the west of Scotland, and in Down and Louth, limestone is absolutely indispensable. But in addition to *directly* affording an essential element to plants, it is also believed to act as a powerful chemical agent in rendering accessible to your crops the stores of fertilizing matters, locked up in an insoluble state, in the rocky particles of the soil, in combination with silica. In granite and many other rocks, silica exists in chemical combination with potash, in a form in which it is but slowly acted upon by the rain; but when these silicates (50) are crushed and mixed with hot lime, and water poured upon them, it is found that after some time chemical changes are produced, by which the silica and the potash are converted into a form in which they can be dissolved in water, and therefore serve for the nourishment of plants. These important chemical changes must also, to some extent, take place in the soil when it is mixed with lime. In many soils which contain an excess of vegetable matter, like our peat bogs,

certain vegetable acids are formed, which frequently render the land *sour* and unfavourable to the growth of useful plants; much of the beneficial effects of *limeing* such soils is ascribed to the lime entering into combination with, and neutralizing, these acids. It also promotes the decay of the inert vegetable matters, and thus not only sets free the inorganic ingredients which they contain, but disposes their elements into forms (carbonic acid, &c.) capable of yielding up food to plants.

246. A compound of sulphur and iron, *sulphuret of iron*, is found in small quantities in almost all the rocks from which soils are derived; you must have observed it sparkling in the sunshine, on the face of the clay-slate and basaltic rocks in many parts of the country, like a sprinkling of brass dust. This compound is insoluble in water, but, by exposure to air and moisture, it unites with oxygen, and is converted into sulphate of iron, "green vitriol" (163), which readily dissolves, and is found to exercise, when in excess, an injurious effect upon the crops. The addition of carbonate of lime, to soils in which this salt is contained, proves useful by decomposing it,—gypsum and insoluble peroxide of iron (48) being formed, while the carbonic acid escapes.

247. *Effects of lime upon plants.*—The effects of lime in improving the quality of the crops to which it has been applied, have long been remarked; thus, when applied to old grass-lands, it extirpates coarse and unpalatable plants, and favours the growth of the tender and nutritious white and red clovers. It is said to add to the quantity of gluten produced by the corn-crops, and to increase the weight of the grain; mixed with salt, it gives strength to the straw on mossy lands, where the crops are so frequently lodged. It is also found not merely to improve the quality of almost every crop, rendering the pea more easily boiled and the potato less watery, but it shortens the period of its growth, and hastens the ripening of both grain and roots.

248. Neither experience nor theory can point out exactly how much lime should be added to a soil. Professor Johnston states, from the results of his calculations, that in Scotland, at least sufficient should be present to give three per cent to a soil "which contains an ordinary proportion of vegetable matter and the other food of plants," which to one entirely destitute of lime, would, when the soil is twelve inches deep,

require an addition of 48 tons of quicklime. To undrained soils it must be applied in greater quantities than when the excess of water has been removed, as the moisture present not merely produces a greater proportion of acid compounds, which it is necessary to neutralise, but prevents its full operation. In determining the quantity of lime required by any particular soil, it is therefore evident we must be guided both by a consideration of its physical qualities, and its chemical composition as determined by analysis.*

249. The state in which lime is applied must materially influence its effects upon the soil. It is, as you are aware, used by farmers:—

1. In the *caustic* state.	Shell lime applied directly from the kiln. Slaked by the addition of water.
2. In the partially *mild* state.	As slaked by absorption of moisture from the air, and in part combined with carbonic acid.
3. In the *mild* state.	As chalk, marl, shell-sand, coral-sand, limestone-gravel, and as burned lime rendered mild by long exposure to the air.

250. For full directions as to the best methods of applying lime in the various states in which it is used, I must refer you to the works of writers on the practice of agriculture. The following general rules will, however, serve to direct you in regulating its application:—

I. That in reclaiming peaty soils, or those composed of intractable clay, or which contain substances injurious to plants (246), it should be applied as hot as possible from the kiln.

* It is only lately that the attention of chemists has been directed to the changes which limestone may undergo by burning; thus, it has been found by analysis (Johnston), that when burned with coal several new compounds are produced, the sulphur which the coal contains uniting with the lime so as to form gypsum, while the silica contained in the earthy matter of the limestone and in the coal, upon the expulsion of the carbonic acid, enters into combination with some of the caustic lime, producing a *silicate of lime*, thus converting the silica into a state in which it *may*, when placed on the soil, contribute to the support of plants.

II. That where the soil is poor in vegetable matters, and especially when lime has already been applied, it should be laid on the land in the *mild* state, or made into a compost with the scourings of ditches, clay, peat-mould, or other vegetable matters. When applied in this compost form, a smaller dose of lime is found to be sufficient, and the fertility of the soil is most effectually maintained.

III. That as it has a tendency to sink down in the soil, it should not be buried too deep.

IV. That on commencing to improve a farm to which lime has not been applied for some time, the most judicious method is to add a sufficient amount of it to influence the composition of the soil, and after five or six years to maintain its condition by short doses, at the rate of about 8 bushels yearly per acre.

V. That quicklime, for the reasons already given, should not be mixed with, or applied at the same time as farm-yard dung, guano, or other manures which afford ammonia by their decay (183).

VI. That where the soil is naturally deep, or where new soil has been brought to the surface and the land has not been properly drained, a larger dose of lime will be required than would be sufficient for a light or well-drained soil.

251. *Marl, shell-sand, coral-sand.*—Besides limestone, there are several other sources of lime accessible to the Irish farmer. The most important of these are the deposits of marl and shell-sand, which are found in so many parts of the kingdom. The term *marl* is applied by the farmer to a kind of calcareous earth, found at the bottom of bogs, and forming beds in the small lakes which exist in so many counties. Agricultural writers usually confine the term to earths containing not less than 20 per cent of lime. In this country, however, the quantity of lime in the substances regarded as marl, varies from 5 to 96 per cent. The marls met with in Ireland differ very much in their composition; some of them contain a considerable amount of organic matter, and are dried with difficulty (*peaty marls*); others, again, appear to be almost entirely composed of minute shells, and crumble readily into powder when exposed to the air (*shell-marls*);

and in some districts, the calcareous matter is mixed with an adhesive clay (*clay-marls*).

252. The following is the composition of some specimens of marls, examined in my laboratory. In 100 parts, they contain respectively as follows:—

	Lecale, Co. Down.	Near Portrush, Co. Antrim.	Ballymoney, Co. Antrim.	Near Armagh.	Do.
Carbonate of Lime	96·50	30·72	54·90	39·60	43·44
Carbonate of Magnesia	1·03	0·82	1·50	0·80	0·55
Organic matter	0·60	3·10	5·00	3·90	2·20
Oxide of Iron and Alumina,	0·30	1·80	1·56	...	...
Insoluble sand	0·40	38·54	10·00	3·70	1·60
Water	1·16	24·96	27·20	52·00	50·60
	99·99*	99·94	100·16	100·00	98·39

Besides therefore conveying to the soil, when applied as manure, a considerable amount of carbonate of lime, these marls, you perceive, would also enrich it by the addition of other ingredients useful to plants. They also usually contain a minute quantity of phosphate of lime, which must contribute to their fertilizing power. So far as their chief ingredient, lime, is concerned, their *chemical* effect upon the soil must be the same as that exerted by *mild* lime. The extremely minute state of division, however, in which the carbonate of lime exists in marls, will facilitate its action, and the organic matter associated with it, will render its effects less injurious upon soils poor in vegetable matter. Peaty marls usually retain a large amount of water, which renders their removal from the bogs expensive; it has, therefore, been recommended to burn them;† and Liebig, who attributes their efficacy, as manure, chiefly to the changes produced by the lime contained in them on the clay of the soil, strongly advises that burnt marl should in all cases be

* This marl consisted chiefly of minute shells, and had been partially dried by exposure to the air; the other specimens were *peaty* marls.

† Wet marls may also be dried, by mixing them with shell lime, which will become slaked at the expense of the water of the marl.

preferred. This plan of treating them is, however, only to be adopted when your object is merely to obtain the chemical effects of the lime present.

253. About thirty years ago, enormous quantities of the powdery marl, such as that from the barony of Lecale, of which the analysis is given above, were applied to the fields of Down, and with such beneficial effects, it is said, as in many instances to raise the value of the land fourfold. But after a time the produce decreased, and marl fell into disrepute as a manure, and has not for some years been much employed in that district. And so it will always happen, until farmers become acquainted with the nature of the substances which they apply to their fields. Precisely the same thing occurred in Nottinghamshire, with regard to bones. At their first introduction, their price being low, it was imagined that, as in small quantity they had done good to the soil, a larger supply should be even more useful; but after some time, to the great disappointment of the farmers, good effects ceased to follow their application, and it was not until the Duke of Portland, by the publication of the results of experiments made on his farm, convinced them that the soil had been overcharged with bone earth, that they directed their attention to other applications. The farmers of Down, in the grain exported from Strangford and Killough, had, for several years, taken away from their farms *nine or ten* of the materials which rendered them fertile, only *two or three* of which could be replaced in the marl used to keep up the condition of the soil.

254. *Shell-sand.*—Valuable collections of sand, containing a large amount of broken shells, exist on the coasts in many parts of Ireland. As this sand usually contains both carbonate of lime and animal matter, derived from the shells, and some of the saline ingredients of the sea-water, it must possess considerable efficacy as manure. It may also, like marl, be expected to convey to the soil a small amount of phosphate of lime. It occurs of various degrees of fineness, and, as might be expected, differs very much in value in different localities. The fresh shell-sand from the sea-shore should always be preferred to that which has been long exposed at a distance from the coast, as it will contain a larger amount of animal matter capable of affording ammonia by its decay.

255. Two specimens of shell-sand from the county of Donegal, lately examined, were found to possess the following composition:—

	Rathmullan.	Melmore, Mulroy Bay.
Carbonate of Lime	74·40	54·36
———— of Magnesia	0·69	3·78
Oxide of Iron and Alumina	1·30	0·36
Phosphate of Lime	...	...
Organic matter	5·10	5·56
Sand and Siliceous matter	16·60	35·36
Water	1·50	0·56
	99·59	99·98

On the coasts of France, shell-sand is much valued, and is applied to the land at the rate of 10 to 15 tons per acre. In addition to the large amount of carbonate of lime and other useful ingredients which it usually contains, Boussingault calculates that 100 tons of it would convey to the soil as much nitrogen (derived from the animal matter) as 32½ tons of farm-yard manure.

256. *Coral-sand.*—This substance, which is procured in large quantities by the fishermen on the south coast of Ireland, affords the farmer another valuable source of lime. It resembles shell-sand in its fertilizing qualities, but contains a larger amount of animal matter, and being therefore richer in nitrogen, will prove more immediately active.

257. *Phosphate of Lime.*—I have already explained to you that bones (199) owe much of their fertilizing qualities to the compounds of phosphoric acid which they contain. By referring to the table, at p. 99, you may observe that that acid is an essential ingredient of all the plants which you cultivate, and is especially required for the production of those parts of your crops valuable for food. It exists in exceedingly minute quantities in even the most fertile soils, and every means of obtaining supplies of it must, therefore, be of great importance to agriculture. Some years ago, great interest was excited by the discovery, in Spain, of a mineral called *apatite*, which contained so much as 37 per cent of phosphoric acid; and recently, considerable attention has been directed to the discovery of Professor Henslow, that in certain rocks in Suffolk and Essex, there exist beds of water-worn nodules, which have been termed *coprolites*,* containing so much as

* These curious nodules are supposed by geologists to be the fossil dung of extinct animals.

60 per cent of phosphate of lime. Many hundred tons of these coprolites have lately been used for manure, and they have even been applied dissolved in sulphuric acid, as a substitute for "vitriolized bones," with the very best results. It has already been mentioned (132), that in the Greensand and other rocks, constituting what is termed *the chalk formation*, which covers a considerable surface in England, and in Ireland extends, with occasional interruptions, from Moira in Down to Lough Foyle in Derry, a considerable amount of phosphate of lime has also been found to exist. It is chiefly in the Greensand, which appears to have been used several years ago in some parts of Antrim, with good effects, as a manure for both potatoes and oats, that that valuable substance has been discovered.*

258. *Sulphate of Lime.*—This substance, which is also known by the names of *plaster of Paris*, *alabaster*, and *gypsum*, has already been recommended as an important addition to the manure heap (183); but, besides its use in the preservation of other manures, it has, for a very long period, been extensively applied as a fertilizer in various parts of Europe, and is at present one of the most favourite applications of the farmers in many parts of the United States of America. At one time, it was believed that it was capable of increasing the produce of every description of crop; but, from the results of careful experiments made by experienced agriculturists, both in France and England, more correct opinions of its fertilizing qualities are now entertained. The use of this manure was considered of so great importance in France, that a particular inquiry into the circumstances connected with its employment and effects, was considered worthy of the attention of the government, and a report on all the information collected was made to the Royal Central Agricultural Society of France. "The following series of questions and answers, I believe," says Boussingault, "embrace most of the points of any interest connected with the employment of gypsum. 1st, Does plaster act favourably on artificial meadows? Of 43 opinions given, 40 are in the affirmative, and 3 in the negative. 2d, Does it act favourably on artificial meadows, the soil of which is very damp?

* A nodule, discovered in the greensand, near Carrickfergus, by Mr. M'Adam, and examined in my laboratory, was found to contain so much as 42 per cent of phosphate of lime.

Ten opinions given; unanimously, no. 3d, Will it supply the place of organic manure? or, will a barren soil be converted into a fertile soil by the use of it? Seven answers given; unanimously, no. 4th, Does gypsum sensibly increase the crops of the Cereals? Of 32 opinions, 30 are negative, and 2 affirmative."

259. Gypsum may be applied either in the burned or unburned state, the only change produced by burning it being the expulsion of the water which it contains. It is sparingly soluble in water, and is usually applied as a top-dressing in calm, moist weather; and its effects are said to be more apparent when the white powdered gypsum adheres to the leaves and stalks of the young grasses (Mr. C. Johnson). It is said that its presence in the soil causes the seeds of peas and beans to become hard, so that they are not easily boiled. As this mineral manure exists in considerable quantity in the north of Ireland, and can be obtained from England at a very cheap rate, it should receive more attention in this country.

260. *The refuse lime of the gas-works* has lately been employed as a manure, in the neighbourhood of towns where establishments for the manufacture of gas exist. From a half to two-thirds of its weight usually consists of carbonate of lime, and it also contains variable proportions of caustic lime, gypsum, coal-tar, and compounds of sulphur. It may be interesting to mention the purpose for which so much lime is used in the gas-works. When coal is distilled, along with the illuminating gas produced, certain volatile bodies are also evolved, which, as they would interfere with its purity, it is necessary to remove; thus carbonic acid gas (24) and ammonia, and the disagreeable smelling gas, sulphuretted hydrogen, are given off (*see page* 57). The manufacturer, however, by passing the mixed gases over slaked lime, is enabled to detain the carbonic acid and sulphuretted hydrogen, and, as it were, sifts the illuminating gas from these impurities. The compounds of sulphur and lime which are produced, dissolve in water, and exercise an injurious effect upon plants; but, by exposure to the air, these salts are converted into gypsum, and are thus rendered useful applications to the soil; so that if gas-lime is to be used as manure, this precaution should always be adopted. It has been used, with great advantage, in the neighbourhood of Belfast, made into a compost with weeds, the seeds of

which it completely destroys, as an application to grass-land. It is usually applied at the rate of 6 tons to the acre, and is sold in Belfast at 1*s.* 8*d.* per ton. At present, this substance, which might be usefully employed were its proper treatment generally known, is, I am informed, thrown away at several gas establishments.

261. *Ammoniacal liquor of the gas-works.*—The preparation of coal-gas exhibits several beautiful applications of chemical knowledge; thus, the manufacturer finds in lime a cheap and effectual means of purifying the gas from carbonic acid and sulphuretted hydrogen, the presence of which would materially affect the brilliancy of its flame; and is also enabled, by a peculiar arrangement of his apparatus, to separate from it certain liquid products which possess considerable commercial value. One of these is the watery fluid known as *gas, or ammoniacal liquor.* This liquor is found to hold in solution variable quantities of the carbonate and other salts of ammonia. It is at present, in many places, used for the preparation of a salt called *sulphate of ammonia,* which is formed by adding sulphuric acid to it, and evaporating to dryness. You may recollect that it is this compound which is produced, when sulphuric acid or gypsum is mixed with fermenting urine. Sulphate of ammonia has been used, with good effects, as an application to both wheat and potatoes;* 100 lbs. of it usually contain 35 lbs. of ammonia, but it is occasionally adulterated with sulphate of soda (52) and other cheap salts.† Its present wholesale price in London is 16*s.* per cwt. *The gas liquor* can be obtained at a very low price, and has been found a useful manure for grass and clover. It should be diluted, before its application, with 3 or 4 times its bulk of water, and its effect will be rendered more permanent by neutralizing it (13) with some sulphuric acid, or by mixing some gypsum with it to *fix* the ammonia. It is applied at the rate of 100 gallons per acre.

262. *Lime, salt, and peat-mould.*—A compost formed of

* The application of a mixture of sulphate of ammonia and vitriolized bones, has been found exceedingly useful in improving the verdure and destroying the moss which springs up in old worn-out lawns. 1½ cwt. of the sulphate of ammonia, and 5 bushels of bones, will be sufficient for an acre.

† The teacher may readily test the purity of a sample of sulphate of ammonia, by heating a little of it, on the point of a knife, over the spirit-lamp, when, if pure, it will all be converted into vapour.

these substances is much valued in many districts. The good effects of salt have already been mentioned. It has been used for a long period as a manure, though, when applied in too large quantities, it totally destroys vegetation. The refuse salt of the provision stores can be procured at a very low price; and, as it is mixed with blood and other animal matters, it will be found even more useful than pure salt for manuring. The best method of intimately mixing lime and salt, is to dissolve the salt in water and use it for slaking the lime; the effects of the mixture are mutual decomposition of the lime and salt (chloride of sodium), chloride of calcium and caustic soda being produced, both of which are readily soluble in water. When peat-mould is added, a compost is formed, of great value as a manure for soils deficient in vegetable matter, and requiring lime and soda.

263. *Soot*, which is occasionally employed as a top-dressing to grass and wheat, is a variable mixture of clayey matters, iron, sulphate of ammonia, gypsum, and certain organic compounds. Its fertilizing qualities are to be ascribed chiefly to the sulphate of ammonia which it contains.* The amount of this ingredient, which different samples are capable of affording, is shown by analysis to vary from 10 to 30 per cent. It should be applied in damp weather.

* The teacher may convince his pupils that ammonia is contained in soot, by moistening a little of it with water, and mixing it with quicklime, when a pungent ammoniacal odour will be perceived.

INDEX.

THE END.