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MEAT, MILK, AND WHEAT:

AN

ELEMENTARY INTRODUCTION

TO THE

CHEMISTRY OF FARMING.

TO WHICH IS ADDED

A REVIEW OF THE QUESTIONS AT ISSUE BETWEEN

MR. LAWES AND BARON LIEBIG.

By THOMAS DYKE ACLAND, Jun.

WORK AND LEARN.

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TO

HENRY WENTWORTH ACLAND,

ONCE A WILLING PUPIL,

NOW A PATIENT TEACHER,

ALWAYS THE KINDEST OF BROTHERS,

IS DUE

WHATEVER TRUTH IS HERE CONTAINED.

NOTICE.

I HAVE been frequently requested to reprint the following Lecture, accompanied with further details to fit it for elementary teaching. I have deferred complying with the request in hopes of rendering it more useful by corrections and additions. As I see no prospect of being able to fulfil this intention, it seems better to publish it as it was first written. Excellent manuals for elementary instruction and scientific illustration abound. The only purpose this outline can serve is to awaken an interest in the chemical meaning of every-day facts known to all farmers, and I commend it to the indulgence of my fellow-labourers in Agricultural Education.

The controversy between Baron Liebig and Mr. Lawes may be considered as now closed. This struggle between science and practice has been most instructive, and a record of its chief points may not be without its value to the novice in chemistry. The last notice of the subject in the Bath and West of England Journal just published is appended.

May 30, 1857.

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CHEMISTRY OF PRACTICAL FARMING.

SOME apology may be due to the reader for the matter and style of the following attempt to introduce chemistry to the fireside of the practical farmer. The attempt would not have been made, but for clear proofs that several erroneous or misapplied notions on chemical subjects are beginning to float about the agricultural world, and that sensible men have been led into serious practical mistakes in consequence. The time is arrived when the farmer who desires to protect himself against fraud, by the aid of the chemist, should know enough of the first principles of natural science to put his questions aright, and to appreciate the answers for what they are worth.

As to the matter of the lecture, it contains nothing new; still it may not have been a waste of time to try to connect the business of the field and the market with reverent inquiries into the wonderful workings of Nature, and to show that some of the most highly-gifted men of our time have not laboured in vain to aid the farmer in increasing the food of the people.

Moreover, while I must caution my younger readers against the notion that they can form sound conclusions either on scientific or practical questions without laborious attention, aided by previous discipline of mind, by a careful study of the meaning of words, and of the principles of exact calculation, I would fain incite them to observe for themselves, and to add to the store of well-recorded facts, from the comparison of which alone true principles can be drawn.

I have retained the form of a lecture, at the risk of seeming to use language too colloquial for the subject; not that I would attempt to substitute popular for technical language as a means of studying science (nothing could be more absurd); but I thought that something might be done in the way of selection and arrangement to bring before men of practical habits the topics most likely to give them faith in accurate experiments, and to show the value of precise language and ideas. For this purpose nearly all allusion to the beautiful laws of chemical atoms and proportions has been postponed; and in every case a reference to definite facts, of every-day experience, precedes the use of a philosophical term. I need not say that I make no pretensions to scientific attainments; I can only hope that the great pains which I have taken to avoid serious error may have been successful.

PART THE FIRST.

OBJECT OF THE LECTURE.

IT may be expected that in delivering a lecture on agricultural chemistry I should say what it is, and what is the use of it.

First, let me say what agricultural chemistry will not do: it will not teach farming; farming is an art, and, like all other arts, it must be learned by practice. One of the greatest ancient philosophers said in a treatise on morals, a man can only become virtuous by doing good actions, just as a man can only become a shoemaker by making shoes. So, to understand farming, a man must farm: there is no other way.

In the practical operations of the field and the yard, the farmer is a better teacher than the professor, because his habits of business enable him to judge whether an improvement will pay or not. It is on sound judgment on that point, on a knowledge of our own climate and good marketing habits, that success in farming depends, as a money question, more than on abstract scientific knowledge.

But there is one point on which those who know most about farming will admit the imperfection of their knowledge, and that is the rational explanation of their own practice; they know that one plan answers and another does not, but they are often at a loss to say why. Now it must surely raise even a day-labourer in the scale of intelligent beings, and give him nobler pleasures, if he can go about his usual employment not merely as a task to be got over, but if he can trace the hand of his Maker in the wonderful processes of nature. He will not merely submit to the stern laws of nature, and accept the bountiful gifts she brings him, without seeing any connection between them; but every walk he takes in his fields and every book he reads will bring more food for his mind and his heart than before. All, then, which I propose on this occasion is to endeavour to contribute to your enjoyment as observant and thinking beings by throwing some light on the daily occupations in which you are engaged, as far as they admit of an explanation on chemical principles. I must leave it to you to judge how far, if at all, these principles are in accordance with existing practices, and how far they admit of any new practical application.

Practice and Science—wherein they differ.

Before, however, I can explain what agricultural chemistry is, I wish to make a remark on the difference between a practical and scientific way of looking at things.

The practical man and the philosopher both desire to *get at the truth*, but for different ends. The practical man is he whose business it is to make or to do something. He is always acting, and can spare little time for thinking, except for some object close at hand; on most points he has made up his mind, and cannot go over the whole ground again, or if he does he must come to a decision quickly, act upon it at once, and wait the result perhaps for a year. The consequence of this is that his powers of observation are very much sharpened in a certain way, but he is obliged to look at facts in the rough, and generally without much classification or arrangement, for which, in fact, his previous education has rarely fitted him.

The man of science, on the other hand, aims at knowing rather than at doing; his great concern with results is to find out their causes; he tries not to produce effects, but to account for them. This he does first by accumulating and arranging in his head the knowledge of other men of various ages and lands; secondly, by taking up some one point on which little is known and working it gradually out. It is especially his duty to be content to bide his time, to observe individual facts very minutely one at a time and under special conditions, to follow each principle out to its consequences, and to be very cautious in drawing practical conclusions.

It follows that owing to the fact that the farmer and philosopher travel by different roads they do not always give the same account of the country they pass through.

The farmer, being engaged in a struggle with varying seasons, has a lively sense of the obstacles to be overcome, and is an acute observer of common elements of success or failure to a degree which often surprises learned professors. The philosopher looks at facts under assumed and artificial conditions, quite rightly for his proper work, but he sometimes forgets this in applying his knowledge to practical life. He has a tendency to over-estimate possibilities, to calculate expense at a minimum, produce at a maximum: the man of the field calculates by averages, with a wide margin for seasons and bad luck.

But though there be this great difference in their way of dealing with facts, the very difference of their employments shows that they may assist each other, because each has opportunities which the other has not; and, in fact, the leading men in each department have of late years acquired a thorough respect for the judgment of those in the other, when exercised on points falling within their own province. I think farmers are now generally disposed to look for help from science; but they are perhaps not yet fully aware of the amount of laborious, patient toil involved in one honest investigation upon a theoretical point. When I tell you that many analyses take two or three weeks' work of men of first-rate ability, and that a conscientious chemist will begin his work all over again if he spills a single drop containing far less than the 1000th part of a grain of the substance under examination, you may form some idea of the amount of work locked up in some thousands of analyses made by men of European reputation during the last half-century. Yet on how few subjects in practical agriculture do they yet venture to speak positively!

AGRICULTURAL CHEMISTRY—ITS RELATIONS TO OTHER KNOWLEDGE.

Agricultural science, speaking generally, has for its object to ascertain the laws of Nature which regulate the growth of vegetables and animals when they are artificially produced. By these laws the tiller of the soil is inevitably bound; and he must try to understand them, if he hopes to modify them, as his Creator allows him to do, by labour and skill. Science, in fact, points out to practice its limits and conditions, and at the same time suggests to it fresh hopes and new inducements to exertion.

Agricultural chemistry is, of course, but one branch of a much larger subject. Before we can understand the laws by which living things grow, we must accurately know the laws of lifeless matter, or matter in general: of that dust whence our own bodies were taken, and to which they will return.

The properties of matter are of two different kinds. In the first and simplest case, bodies or substances act upon each other only by pressure or change of place, remaining in other respects as they were before. The properties so called into action are called *mechanical:* such, for instance, is the action of frost on clods of earth, of sand and clay when mixed; and generally we may say that the direct action of tillage on soil is mechanical. But in the second case, different substances have peculiar properties of their own; and these different substances, when brought together under suitable circumstances, undergo peculiar alterations, and exchange the properties which they had previously for new properties. For instance, why does iron rust? Because a portion of air and of water has united with the iron, altered its properties, and actually increased its weight, instead of wasting some of it away to nothing. Why does limestone in the kiln lose half its weight, and become quicklime? and why does quicklime again become mild and gain weight again by exposure to the air? simply because certain changes have taken place between the lime and the air under the influence of heat and moisture. In like manner, when cider ferments, and bodies putrefy, changes are going on between different substances of which the bodies are composed. These changes are the consequence of *chemical* properties; the bodies are said to react upon each other, whence the term chemical re-agents is applied to the tests by which one substance is known from another.

It is of the greatest consequence in all inquiries into the science of farming to keep clearly in mind the distinction between mechanical action and chemical action; and it is not less important to bear in mind that, besides these two causes for the effects we observe, there is a third, which is that mysterious agency of which we know so little—Life. Its operation we call, for want of a better name, *vital force.* Thus you will see that there are three departments of inquiry bearing on the whole of the science of agriculture :—

Vital action, of which the science is Physiology;

Chemical action; and

Mechanical action, treated of by Natural Philosophy.

Chemistry stands between and touches on the borders of Physiology on the one hand and of Natural Philosophy on the other, inasmuch as many of the processes which go on in the interior of animals and plants are explained on chemical principles; and, on the other hand, chemical forces are frequently intermixed with those which are merely mechanical. These three sciences are, in fact, the master-keys opening the way to all the more special branches of natural knowledge, and to all accurate acquaintance with the principles of Arts and Manufactures; and what is commonly called Agricultural Chemistry, treating as it does of the inert soil, of powerful chemical manures, and of the food of plants and animals, has a special reference to the principles of all three, namely, Natural Philosophy, General Chemistry, and Physiology.

A few words must now be added on the objects aimed at in chemical inquiries, and on the principles involved in them.

The Object of Chemistry.—The Elements.

One of the principal objects of chemistry is to ascertain the different constituent parts of which bodies are made.

In ancient times it used to be supposed that all things were formed from what were called the four elements—earth, water, air, and fire. We know now that each of these four is a compound of simple substances, and though it is not uncommon to hear the ancients ridiculed for their imperfect knowledge of nature, this division of theirs is not at all to be despised. Earth, water, and air represent to us the three states in which many things may be made to exist, namely—the solid state, the liquid state, and the state of vapour or gas. Water, for instance, may be made solid by cold, and turned into vapour by heat. The same effects may be produced on quicksilver and on several other common substances.

Before, then, we enter upon the inquiry " What materials are animals and vegetables formed from ? and how are these large solid masses of living beings accumulated, and again resolved apparently into nothing ? " I must make one demand on your thinking powers. Can you conceive that what is called a gas need not be a thing by itself which is always a gas? but are you prepared to believe that the same quantity of matter, the same particles ascertained by weight on the scale-beam, may appear sometimes as a gas, sometimes as a liquid, and sometimes as a solid ? and that this change of state, to speak generally, depends simply on the fact that the particles of matter are expanded or moved farther apart from each other by the action of heat ? and that on the removal of the heat they may be condensed or brought nearer together either by pressure, that is, by squeezing, or by the mutual attraction of one for another ? Different kinds of attraction there may be, but we need not enter into that question here.

Every one has heard, for instance, of the oxygen of the air, which is commonly called oxygen gas, and which used to be called "*vital air*," as opposed to "fixed air." It is that part of the air which our bodies require to draw in through the lungs, and without a supply of which life would instantly cease ; a supply of it is also necessary to keep a fire or candle burning. But oxygen is also a part of water. A gallon of water weighs 10 lbs. : throw away one-tenth part, or 1 lb. ; of the remaining 9 lbs. exactly 8 lbs. are oxygen. There is also oxygen in rusty iron or iron ore, and in the ores of many metals. The oxygen is there in a solid state, and, as I said before, adds considerably to the weight of the pure metal, instead of wasting it away and making it lighter. In fact, oxygen is in the state of a gas in our breath, in the state of a liquid in our blood, in the state of a solid in our bones. It pervades all nature, animate and inanimate : the solid earth, the tossing ocean, and the elastic atmosphere.

You will therefore, I trust, not set me down for a wild theorist if I try to prove to you, by-and-by, that the greater part of the produce of your farms comes out of the air ; and in the mean time perhaps you will be entertained by the following account of yourselves, given by an eminent chemist:—

"Science has demonstrated that man, the being who performs all these wonders, is formed of condensed air (or solidified and liquefied gases): that he lives on condensed as well as uncondensed air, and clothes himself in condensed air; that he prepares his food by means of condensed air, and by means of the same agent moves the heaviest weights with the velocity of the wind. But the strangest part of the matter is that thousands of these tabernacles formed of condensed air, and going on two legs, occasionally, and on account of the production and supply of those forms of condensed air which they require for food and clothing, or on account of their honour and power, destroy each other in pitched battles by means of condensed air."

We may assume it to be now admitted that earth, water, and air are not elements, but compounds in certain states, *i. e.* more or less compressed or expanded, whether by mechanical or chemical forces. The efforts of modern chemists have been, in great measure, directed to the work of decomposing or splitting up all bodies into their true elements: that is, to find out substances with special properties, yet so simple that they cannot be divided again into simpler substances, and this is all which is meant by an element, namely, that it is a well-defined substance, and that, in the present state of chemistry, man is unable to decompose it, or to prove it to be compounded of other substances.

In order to gain a really sound knowledge of chemistry it is necessary to study the characteristic features of every element separately, and then to learn the laws by which they enter into combination with each other. This cannot be done by reading a book, nor even by listening to a lecture. Practical chemistry is like practical farming. The student, who is in earnest, must go to work at it in a laboratory, which means a place of work, and he will learn more by following up his own blunders than by the most lucid teaching of the professor.

The chemist has to put two questions to every body which he examines: 1. Of what parts is it composed? 2. How do these parts combine together and act on each other? From these two questions result two different modes of studying chemistry, which I may illustrate in this way. If you wanted to make one of your sons an engineer or mechanic, you might either show him a piece of mechanism at work, and let him pull it to pieces; or you might give him each of the parts separately, explain their respective uses, and teach him to make a new machine. So in chemistry you may take each separate element, possessing well-defined and peculiar properties which chemists have been unable to break up into simpler substances; you may study all these properties in detail, and their action on all other bodies, building up one compound after another, from the simplest to the most complex. This is called the synthetical method, or synthesis, which means putting things together. It is the process of the child, when it puts letters together to form words, and words to form sentences. It is also the process of the mathematician, who rears on the basis of a few simple definitions and axioms his gigantic superstructure. It is, in fact, the proper way to master an accurate science thoroughly, and therefore the proper way to study Chemistry.

But where the object is to interest the practical man, rather than to train and educate the man of science, it may be more suitable to take the common things around us, which are all highly complicated in their chemical structure, and pull them to pieces: that is, trace them backwards to the simplest parts of which they are composed. This is called the analytical method of treatment, or analysis.

But what is analysis? The word means simply to unloose, or to resolve a whole into its parts. Let me give you one or two simple instances. When wheat has to be prepared for market it is first threshed, that is, the corn is loosened from the ear by beating. If you use one of the beautiful combined thrashing-machines, you at the same time separate your crop into the several portions of straw, chaff, tailings, and best corn. This separation is *mechanical* analysis: you divide your crop by mechanical forces alone.

Take the case of milk. You first separate the cream from the skim-milk. In Devonshire you scald the milk in order to loosen the hold which the curdy matter has on the buttery part, and you so far analyse the milk by separating the butter with the aid of heat, and complete the process mechanically in the churn; but the cheese-maker does more; by the use of rennet she introduces a very delicate chemical process, by means of which she renders the curd insoluble, and separates it from the whey. These simple processes of the dairy are, in fact, a specimen of chemical analysis. They are not, of course, exact enough for scientific requirements, but they serve to illustrate the meaning of an operation so often talked of.

I propose, then, instead of commencing in the usual way with a description of the elements separately, to bring before you a few of the common products of the farm, just in the form in which you meet with them, and to show you that they consist of certain substances easily distinguished one from another, and how these substances are to be recognised both in animals and vegetables; we shall then inquire whether these substances are not themselves compounded of simpler elements, and endeavour to trace them to their origin. Having thus, as I hope, given you something like a tangible notion of the various substances necessary to the growth of your farm produce, I shall show, in a practical form, what substances are removed from a farm in the ordinary course of English farming, and how they are to be replaced; and, in dealing with this part of the subject, I shall have to give you some account of the connection between science and practice established by some leading members of the Royal Agricultural Society of England.

And now allow me on this occasion instead of *Agricultural Chemistry* to use the term *Chemistry of Practical Farming*. There may not be much difference; but I wish to show that my object is not to bring practice to be judged of by science, but to draw science out of practice. We will begin with the common sorts of agricultural produce.

The different kinds of Food produced on a Farm.

The three principal products of the farm are meat, dairy produce, and corn. Let us, then, take them in succession, and after some simple fashion analyse them; only we must learn as we go on a little accuracy in such matters. It will be enough to state, in a general way, that the products of the farm belong to the animal and vegetable kingdom; and it is a part of our most familiar knowledge that animal life is supported directly or indirectly by vegetables, while vegetables in some sense or other are sustained by the earth, the rain, and the air; thus the mineral kingdom furnishes the elements out of which vegetables are built up, and the vegetables supply the food of animals. This is the chemistry of nature; man cannot imitate her in the marvellous processes of life; in dealing with the products of life he can only undo her work by pulling it to pieces.

We begin, then, at the highest point with the animal. We will take as the type of the highest form of organisation in farm produce a full-grown and well-fed sheep, certainly not the least important article on the farm either to the producer or the consumer, furnishing, as it does, the most nourishing and wholesome food, warm clothing, and light.

The most obvious divisions of the sheep's carcase are bone, lean flesh, fat, wool, besides the skin, sinews, and other matters yielding size and glue; nor must we forget the blood which conveys the food, after it has been digested, to all parts of the body, and therefore contains all the materials out of which the body is formed.

Component parts of an Animal.—If you look at the annexed table you will see the parts of a sheep arranged in three principal divisions: at the head of the first column is fat, at the head of the second flesh, and of the third bone.* You will not

* The columns are marked with the letters A, E, O, being the vowels of the

fail to recognise the following distinctions. Fat, after it has been boiled down and separated from the greaves, is pure tallow, and may be entirely burnt away, leaving no ashes behind. Flesh is more difficult to burn; and if you burn it in a clean dish you will find a certain residue of mineral matter in the form of ashes. Bone—by which I mean dry bone, after all the grease and glue have been removed—may be heated red hot, but, when cool, remains of the same weight as it was before being heated, without being consumed.

TABLE I.—Showing the Simplest Division of Substances raised for Food of Man on a Farm.

	A.	E.	O.
MEAT . . .	Fat	Flesh (lean)	Bone (quite dry).
MILK . . .	Butter	Cheese (skim) . . .	Mineral ashes.
WHEAT . .	Starch	Gluten	Ditto.
Distinctive characteristics of each part.	Easily burn quite away. Do not putrefy. Do not give off ammonia.	Do not easily burn. Do putrefy. Do give off ammonia.	Do not burn at all. Do not putrefy. Do not give off ammoina.

Another set of distinctions may be noticed, founded on the tendency to putrefaction. Fat, that is, pure tallow, may be kept for an indefinite time; it may become rancid, but it will not putrefy. Flesh cannot be kept, except by excluding it from the air or by salting; but in its natural state soon putrefies, gives out offensive smells, and disappears, all but a small residue. A familiar illustration of this distinction may be given in the case of potted meat, which is preserved from putrefaction by a coating of fat, on which the air will not act. This distinction is owing to the connection between flesh and ammonia, which is very volatile. Putrefaction or decomposition easily ensues in any substance which is capable of generating ammonia. We shall see that in this last point is involved a principle of immense importance to the farmer, in regard to the economy of the food of animals and the food of plants. Bone will not putrefy after the glue has been taken out of it.

Component parts of Milk.—We will next take milk, the type of perfect food, being, in fact, that fluid from which alone young animals derive their fat, flesh, and bone, in the early period of their growth. The parts of milk may be arranged in the same manner as those of the animal. First, we have *butter*, which, if quite pure (for common butter contains a mixture of cheesy matter), will entirely burn away like oil; it will not putrefy by exposure to the air, that is, it will not soon disappear, though it may turn rancid and become disagreeable in taste. There is

three words fat, flesh, bone, and this distinction will be observed in other tables to assist the memory.

also a certain quantity of sugar in milk, which is characterised by the same tendency not to putrefy. Secondly, we have *cheesy matter*, which, under the influence of moisture, will putrefy, and which burns slowly and with difficulty, giving out a smell of burnt hair or ammonia. And, lastly, the whey, which, when entirely freed from butter, sugar, and cheese, and evaporated, will leave a considerable portion of dry mineral matter which is not combustible. The quantity of the ashes so left is about ½ per cent. Ten gallons of milk contain about ½ lb. weight of solid mineral matter, which cannot be burnt away.

Component parts of Wheat.—We will presently trace these several classes of food to their origin, through the grass, hay, turnips, &c., consumed by the animal; but, first, let us look at one other essential article of food, the staff of life, used by civilised man in the form of bread. If you grind up wheat, and knead the flour up in plenty of water for a considerable time, in fact, as long as the water has a milky appearance, you will separate it into two parts. The turbid milky water contains starch, which will be deposited when it settles, and the dough which remains, after all the milky substance has been washed out of it, will be a tough, elastic, transparent mass, which, from its sticky nature, is called gluten. The proportion of this gluten varies as much as from 10 per cent. to 20 per cent. in different samples of wheat, the difference depending, among other conditions, on the climate or season in which the wheat is grown. The starch which has settled down from the milky liquid is more than half of the weight of the whole grain. There is also a small proportion of mineral matter in wheat, which cannot be burnt away, and will be left in the form of ashes.

On looking now at the results which are stated in the table, it is impossible not to be struck by the fact of the remarkable likeness subsisting between the three principal sources of human food, which will appear more striking when we have considered the following question :—

WHAT ARE THE USES OF EACH KIND OF FOOD?

The necessity for food arises from the constant waste which is going on in all animal bodies. Of this waste there are two causes, breathing and moving, or, in other words, the respiration of the lungs and the exertion of the muscles. The action of breathing is similar to that which goes on in the fireplace, or in the burning of a candle. Our lungs are the fireplace :* we draw in fresh air through the windpipe, and when we give

* The statement in the text may be not strictly accurate; but it would require too much chemical detail to explain the process by which it is now supposed that heat is generated and diffused throughout the whole body.

out our breath we send forth not the same fresh air that we drew in, but an air which is not unlike that which goes up the chimney from a clear-burning fire. And there is good reason for believing that by this action of the breath the animal heat is kept up. But, as the fire cannot be kept alive without wood or coal and fresh air, so our lungs cannot act unless we have a supply of food fit to burn and fresh air to burn it with. Speaking very roughly, a strong healthy man burns in his lungs daily an amount of fuel equal to about ¾ lb. of coal.* The other cause of a demand for food is the exertion of muscular force. It is supposed that, every time we move our limbs or any part of our body, a certain change takes place in the substance of which they are composed, and that this change involves a waste of the flesh or muscle by which the force is exerted: the tissues so used up pass off from the body in various ways, and are replaced by those materials of food which possess the requisite composition.

From this short statement, then, you will plainly see that there are two great purposes to be fulfilled by our food—the supply of heat and the support of force. Now, then, if you will look again at the table, you will see that the three descriptions of food there exhibited in the first column—viz. fat, butter, and starch—are all eminently fitted for combustion or keeping up the animal warmth. Whereas the three substances in the second column are distinguished from those in the first by not being easily burnt or decomposed. The fact is that animal force is entirely exercised by lean flesh or muscle; and it is a very remarkable fact that cheese (skim cheese, not rich Stilton) in the case of milk, and the gluten in the case of the bread, are composed of exactly the same materials as lean flesh.

Of the *bone* it is not necessary to say more here than to point out to you that the constituents of bone are contained in milk and bread: they are carried by the blood about the body wherever required, and in some cases bone is absorbed again and cast out of the body.

I cannot refrain from pointing out to you the wonderful providential arrangement thus disclosed to us by the knowledge of these facts. The labouring man, who is constantly in motion, requires food which will support the waste of muscular fibre, and this is afforded by the common cheese made of skim-milk; and it so happens that butter being, in some degree, an article of luxury, the demand for it among those in easy circumstances is such that its price is enhanced; and in consequence of this higher price of butter the dairyman is able to sell common cheese at a lower rate to the working-man. I have ascertained,

* 1 lb. of coal will heat 56½ lbs. of water from 32° to 212°, that is, from the freezing to the boiling point.

by conversation with several working-men, that their own experience bears out this statement. One very active man told me that he believed he could work better on common cheese than on flesh meat. It is nevertheless true that fat, such as bacon, is also a valuable element in food for hard-working men; this partly results from its use in keeping up the animal heat, partly because, as I am informed by medical men, it aids in digesting other food.

Classification of the Materials of Food.

Before we trace the different kinds of food, as gradually developed in practical agriculture, we must take another step in analysing them, and endeavour to *ascertain and classify the materials of which they are made*, and then we shall be better able to trace them to their source. (See Table II., p. 18.)

i. *Meat and Vegetables contain Water.*—If we take a piece of meat or almost any part of a vegetable and subject it in a dry vessel to a heat equal to that of boiling water, but not higher, it will be found to lose some of its weight; and if this warming be carried on in a covered glass vessel it will be seen that steam is passing off, which may be all collected and condensed into water. That this is true of liquids, such as blood and milk, will be obvious. But it will perhaps be somewhat surprising that there is about the same quantity of water in lean flesh as there is in blood: water exists to a large extent in pure cheese and in wheaten flour, and to a still larger extent in turnips, cabbages, and grass. With regard to the oily matters, such as butter and fat, they will not be found when pure to give off water in the form of steam at the temperature of boiling water. Animal fats, however, do contain an appreciable amount of the elements of water, but not in the same proportion as that in which they are contained in water; and one of the causes why they burn as they do is the tendency of their elements, in contact with air, to form water again among other products of combustion in its true proportions; in effecting this union an intense chemical action takes place attended by the phenomena of heat and light; and this is what we mean by combustion, namely, chemical union attended by light and heat.*

ii. *Animals and Vegetables contain Carbon.*—When by the process of drying to the heat of boiling water we have removed whatever water we can so separate, we may next subject the meat

* There is another chemical change, commonly called rotting or decay; this, as is well known, is generally accompanied by dampness, showing the presence of water. This is, in fact, a chemical union *not attended by light and heat;* to this process of nature Liebig has given a name, which means "slow-burning," Eremacausis—"causis" having the same word-root as "caustic," and meaning combustion.

or the dry flour of wheat to a higher degree of heat in a thin glass vessel over a spirit-lamp, taking care, however, to exclude the air. This is called charring, or dry distillation: you will observe that the meat or the grain now changes colour; it becomes roasted. What, then, is this dark, black substance?

There is also another way in which we may produce a similar appearance. It is well known that if a drop of vitriol fall on a linen garment or on a piece of wood, it will char it or turn it black: what has happened? Vitriol has a most intense thirst for water. It has therefore a strong drying effect, like that of lime, which dries up what comes in contact with it. Only the vitriol acts still more intensely. The vitriol then has dried up all the water; what, then, is the black substance which is left? If you see these effects of charring on a piece of wood, you will not hesitate at once to pronounce the black mass to be charcoal. Well, just as it is charcoal in wood, so is it charcoal in every other vegetable substance, and in the flesh and bones * and fat of animals: the black crust of your loaf of bread is charcoal; the blackened skin of an overdone piece of meat or of a milky pudding is charcoal; and now, if you please, we will give it its proper scientific name, which is *carbon.*—See Table II., column A.

iii. *Some parts of Animals and Vegetables contain Nitrogen.*—In charring animal and vegetable matters you will not fail to notice the distinction already pointed out, that the bodies in column A of Table I., p. 12, give off no smell of burnt hair or ammonia, that those in column E do give out such a smell; we may as well now place in the same class with the lean flesh there mentioned all matters which yield glue, such as skin, cartilage, gelatin of bones, and also wool, which has a character of its own. Wherever this smell of burnt hair takes place, we may infer the existence of a body called nitrogen or azote—an element which invariably enters into lean flesh or muscle, and which it is therefore absolutely essential should be found in the food which supports the action of the muscles and repairs the waste which they are subject to. From the names of this body we derive a distinction which is now very common in works on the science of farming. Fat, butter, sugar, starch are called *non-nitrogenous* or *non-azotized* bodies; while flesh, cheese, and gluten are said to be *nitrogenous* or *azotized.* It may be well also to repeat here that whenever putrefaction takes place ammonia is formed. Ammonia is a compound body, of which about 4-fifths are nitrogen. The nitrogen in living bodies having only a feeble affinity for the bodies with which it is

* I here speak of bone in its natural condition, containing a large proportion of gelatinous matter: the pure mineral part of bone will not blacken in the fire because there is no carbon in it.

there combined, and having a strong tendency to pass into the state of ammonia, as soon as vital force ceases, ammonia is rapidly formed and flies off as a gas; the most offensive smell of putrefying substances is owing to another gas formed with sulphur, and well known as the smell of rotten eggs.—See Table II., column E.

iv. *Some parts of Animals and Vegetables contain Earthy Matters.*—In addition to the elements which we have found [viz. water, carbon, and nitrogen], the animal system always contains two elements, well known as sulphur and phosphorus; these are to be found in those parts of an animal which are in the column E, and also in the curd of milk and the gluten of wheat. If we carry the action of heat one step farther, and burn the meat and wheat in the open air, they will gradually consume away till nothing is left except a small amount of ashes, and in these ashes we shall find, in addition to the elements already named, viz. Phosphorus and Sulphur, which form powerful acids, the following earthy or mineral matters:—

1. Potash and soda, commonly called alkalies.
2. Lime and magnesia, called alkaline earths.
3. Iron, which is always present in the blood.*

These bodies enter into combination with various acids, of which they are the corresponding bases: as for instance, gypsum consists of a combination of sulphuric acid and lime, and is therefore called sulphate of lime. A large part of our bones consists of phosphoric acid in combination with lime and magnesia, called therefore phosphate of lime and phosphate of magnesia.—See Table II., column O.

These ashes of mineral and earthy matter may appear insignificant, but, small as they are, in proportion to the bulk of the bodies in which they are found, they are of the highest importance. A great part of the theory and practice of manuring depends upon them. Certain very small quantities of them are essential to the health of animals and plants; and however abundantly other fertilizers may be supplied, if any one mineral element which the plants or the animals require is inadequately supplied, they sicken and die.

The proportions of the different component parts of blood, and also of meat, milk, and wheat, classified under the four heads just enumerated, are given in the following Table: †—

* This list does not profess scientific accuracy or completeness. Common salt, for instance, consists of chlorine and sodium; and there are other chlorides, but it seemed better here to speak only of familiar substances entering into composition with well-known acids.

† As it is possible that some of my readers may have forgotten their decimal fractions, this table and the next are so arranged, that by disregarding the decimal point altogether the figures may be read as whole numbers, each quantity being

TABLE II.—Showing the Percentage of Constituents of Blood and Food of Man.

		A. Non-Azotized or Non-Nitrogenous.	E. Azotized or Nitrogenous.	O. Mineral.	Authority.
Blood . .	Water 78·0	Pure fat 0·3 . . .	Albumen, &c. 7·0; Colouring matter 13·0	Carbonates, Chlorides, &c. . . . 1·0	Fownes.
Flesh of ox	Water 77·0	Fat all supposed to be removed.	Albumen, fibrin, &c. 19·7	Saline matter 2·0	Johnston.
Bone (fresh)	Water 12·0	Fat 8·0	Gelatin, &c. 24·0	Mineral . . 46·0	Voelcker.
,, (dry)	. .	Fat all removed . . .	Gelatin . 35·0	Phosphates 58·0; Carbonates, &c. 7·0	Johnston, p. 1013.
Milk (cow's)	Water 87·3	Butter 3·0; Sugar 4·4 . . .	Cheese or Caseine 4·8	Phosphates 0·3; Other ash . 0·2	Haidlen, quoted by Fownes, p. 552.
Wheat—reckoning Flour $\frac{5}{6}$; Bran $\frac{1}{6}$	Water—In flour 13·3; In bran 2·5	Starch—In fine French flour 58·5; In coarse Odessa 50·0; Oil in bran . . 0·8; Husk, &c. . . . 9·0	Gluten, Albumen, &c.—In flour . 10·0; In bran . 3·4	Ash—about 2·0	Compiled from various authorities.—See Johnston, 871 &c.

ELEMENTARY SUBSTANCES: WHENCE AND HOW SUPPLIED?

Having ascertained some of the chief substances of which animals and vegetables are made, we proceed now to ask where do these substances come from, and how do they enter into the composition of the living individual?

First, as regards animals. Within a very few years it has been clearly made out that the chief constituents of the animal frame are prepared ready made in the vegetable. By a series of laborious investigations chemists have established the fact that the white of egg, a substance found also in the blood, and to which, on account of its white colour, they give the name of albumen, is almost identical in its composition with the substance of which lean meat chiefly consists, and also with casein, or curd of the milk, and with the gluten of the wheat. It is now generally admitted that the animal receives the substance of his muscle ready prepared into his system from his vegetable food; and those constituents of food which supply the material of muscle and flesh are commonly known by the name *albuminous*, albumen being taken as the type of the group.

With regard to fat, it has been shown that a considerable amount of oily or fatty matter exists in common vegetable food. Chemists have also traced a series of beautiful trans-

in that case taken as containing so many parts out of one thousand, instead of so many per cent. The reader will, then, take no notice of 0, or zero, when it is on the left hand: for instance, the fat in blood is 0·3, that is, three-tenths per cent., or three parts out of a thousand; the fat in butter is 3·0, that is, three per cent., or thirty parts out of a thousand.

formations, by which vegetable fibre is shown to pass into starch, starch into gum, and gum into sugar. All these substances consist of the same elements, yet how various their characters, how important their uses! The rich sweetness of the grape or the apple is thus matured through a gradual ripening from the original formation of vegetable tissue, and this vegetable tissue originally consisted of nothing *but carbon and the elements of water;* nor has any new substance been added. The constituents of food in this group are often called *carbonaceous*, to distinguish them from the nitrogenous or albuminous group.

We need not here enter upon the question how far the vital power of animals may effect changes in their food (a very difficult subject); it is sufficient to have noticed the fact that the principal substances of which animal bodies are composed are also to be found in vegetables ready prepared for their use; and further, that some of the processes of cookery effect changes similar to those which take place in the interior of animals, and so save time in the feeding process.

The animal thus derives the substance of its tissues from vegetables, and these substances, or the elements of them, previously existed in vegetable compounds. I have prepared Table III., to show the proportions in which the different nourishing principles are contained in the articles of food commonly given to animals, namely, grass, roots, grain, and linseed-cake; it is arranged under the same general heads as Table II. (See p. 20.)

The tables make no pretension to scientific accuracy, and though I have generally indicated the source from which I have obtained the figures, I have done so rather to give others the power of correcting my statements than to claim any authority for them. It is very difficult to reduce such calculations to a common standard. Still less do I put these figures before you as a guide in practice. I only wish to point out to you the conclusions arrived at by the investigations of chemists in the laboratory, and to excite you to inquire further into the matter in the field and the stall. I am convinced that much expensive food passes through animals which is never recovered again in the manure. Every effort should be made to prevent this waste, by more accurate study of the component parts of the food and by testing their actual effects on animals. The practical application to be made of this table will be more apparent as the reader proceeds. Perhaps he will then take the trouble, if he thinks it worth while, to turn back to the explanation, which I put in the form of a note in order not to interrupt the course of the argument at present.

NOTE.—The substances in the three columns headed by the

TABLE III.—Showing the Percentage of Constituents of Food of Live Stock.

	Water.	A. Carbonaceous or Non-Nitrogenous.			E. Nitrogenous or Albuminous.	O. Mineral.	Authority.
		Producing Fat or Heat.		Indigestible.	Producing Flesh.	Ashes or Salts.	
		Ready-made Fat.	Starch, Gum, Sugar, &c.	Woody Fibre.	Albumen, Casein, &c.		
GRASS.							
Natural . . .	70·0	1·0	13·0	10·0	3·0	2·0	Averages from Way, R.A.S. xiv. 171.
Water-meadow .	79·0	0·7	8·0	5·0	4·0	2·0	
Artificial (April) .	87·6	0·8	3·9	3·1	3·2	1·3	
Ditto, 2nd crop (June) . .	74·5	0·5	11·2	8·7	2·7	2·2	
ROOTS.							
Turnips . . .	90·0	0·2	6·9	1·9	0·3	0·7	Way and Johnston? in Herring's Tables.
Bulb, Norfolk Bell	92·2	2·1		2·8	1·2	1·0	Voelcker, in Morton's 'Cyclopædia of Agriculture.'
Swede . .	89·5	4·6		3·8	1·4	0·6	
Tops, Norfolk Bell	91·2	0·6		4·0	2·4	1·5	
Swede . .	88·0	1·6		5·0	2·0	2·2	
Mangold . . .	86·0	11·2			1·8	1·0	Voelcker.
Potatoes . . .	75·0	0·3	18·0	4·0	2·0	1·0 about	Johnston, p. 90
Parsnip . . .	82·0	0·5	7·3	8·0	1·2	1·0	Voelcker.
Carrot	87·0	0·2	8·0	3·4	0·7	0·7	
GRAIN.							
Oats	12·0	6·0	50·0	15·0	14·0	3·0	Average from numerous analyses. Voelcker.
Beans	14·0	1·4	43·0		19·7	2·65	Way, R. A. S. x. 495.
Peas	14·9	1·29	47·0		21·4	2·34	
Linseed . . .	10·6	34·7	..	..	28·0	3·5	
Linseed cake (mean of many analyses)	7·0 to 8·0	American 11·4 French . 9·0 English . 13·5	Not determined		Average 27·0	American 6·35 French . 7·9 English . 7·3	Way, R. A. S. x. 479.

Secondly, as to the elementary substances of vegetables.—We have seen that vegetables contain water, carbon, and nitrogen, besides

letter A contain only the elements of fat: they do not contain the elements of fresh meat, and consequently they cannot form ammonia; nor do they contain any of the mineral elements of plants. Consequently it will appear from what follows that they are all but worthless as manure. If they do not bring the farmer a return from the butcher, it is hopeless for him to turn to the miller.

The substances in the column headed E produce flesh; they are therefore valuable also for producing ammonia. One-sixth part, or about 15 per cent. of these albuminous matters, is nitrogen, which would yield ammonia equal to about 1-5th of the whole.

The amount of nitrogen detained in the system of the animal is not great—about 1 lb. per score of increased weight; the some mineral matters ; our next inquiry is, from what sources are these substances derived by the plant?

It is a very common, and certainly not an unnatural, opinion that our crops derive their nourishment from the accumulation of vegetable matter in the soil, or, as it is commonly called in Devonshire, in the meat-earth. Some persons also have been led by what they have seen in books about the elements of carbon and nitrogen, to form a hasty conclusion that plants can imbibe carbon directly from charcoal as a manure; others think that as there is a large amount of nitrogen in the air they can derive the nitrogen from the atmosphere, by absorbing it in its uncombined state through their leaves. Both of these theoretical opinions are considered by competent authorities to be at variance with facts. Again, there was a theory about humus which was very popular a few years ago. It was found that there were in the earth certain acids containing carbon, to which various names, such as humic, ulmic, and others were given, and it was too hastily inferred that they were absorbed by the plant and carried vegetable matter ready formed into its juices.

This theory is now abandoned by most English chemists. It is now supposed that plants derive the supplies of the two principal elements of their structure, their carbon namely and their nitrogen, chiefly from two sources. These sources are *carbonic acid* and *ammonia*, both of which can be absorbed in water, and when so absorbed they can be imbibed by plants through their roots in union with water as a liquid, and through the leaves in union with water as a vapour. I have spoken several times of the elements of water: one of the elements of water united with carbon forms carbonic acid; the other united with nitrogen forms ammonia. I am now to show you that both carbonic acid and ammonia are accessible to plants, and are to

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remainder passes into the dung. Practically, therefore, it will not be far wrong to assume as the amount of ammonia 1-5th of the figures in column E, deducting 1 lb. per score of meat produced, and to look for the rest in the manure. Take, for example, a ton of oil-cake: this will yield (see the Table, E), at 27 per cent., about 600 lbs. of albuminous matter, 100 lbs. of nitrogen, or 120 lbs. of ammonia (round numbers being taken). This, if it all pass into the manure, and *is all saved*, will be worth from 3*l.* to 4*l.* The ready-made fat will be about 200 lbs. Practically, the profit will depend on the proportion of this and of the other matters which the animal can turn into butcher's meat; for, beyond the amount of ammonia above estimated and a trifling quantity of mineral matter, nothing will be found in the manure. Up to what price then will oil-cake pay?

be found in sufficient quantity, either in the soil or in the atmosphere, to supply all our agricultural requirements.

WHAT IS CARBONIC ACID?

One of the most familiar forms in which carbonic acid occurs is in the bubbles which escape during the fermentation of beer or cider: it is sometimes called foul air; it is heavier than common air, and lies at the bottom of large vats: it is that air which is well known to be inconsistent with animal life, and which often extinguishes a candle let down into a closed well. The air which we breathe out of our lungs contains much carbonic acid; the hot air which rises from a candle is chiefly carbonic acid; so that all the pure air in this room would in a short time be turned into carbonic acid and be unfit to breathe if fresh air were not constantly admitted. Half of the weight of common limestone is carbonic acid; it is this which is displaced by heat in the lime-kiln; or it may be displaced by adding a stronger acid to lime which will take its place in union with the lime, and then the carbonic acid which was in the solid stone, having nothing to detain it, makes its escape in effervescence, that is, bubbles of gas rapidly expanding.

We may say, wherever limestone is decomposed, wherever fuel is burnt, wherever animals breathe, or wherever fermentation takes place, during all decay of animals or vegetables, the supply of this gas is going on; and when I remind you that 35 millions of tons * of coals are supposed to be annually raised in this country and to be dispersed throughout the air, you will change your question and ask, not how can plants be formed out of the air, but how can such inconceivable quantities of unwholesome gas be poured forth every year and yet the world be a fit place for man to live in?

The answer opens to us one of those marvellous vistas through which it has been vouchsafed to us to look into the works of the Almighty. It is quite true that, if a special provision had not been made, the atmosphere would long since have been unfit for respiration; but every green field, every forest, even the mighty submarine groves of the ocean, are perpetually refreshing the atmosphere with pure air, taking out of the atmosphere the carbon, and reconverting the carbonic acid into pure vital air.

A few words on the growth of plants will put this in a clear point of view.

Vegetables generally act in this way. Each of their seeds contains in itself an embryo plant, which, under the influence of heat and moisture, swells and pushes out a root downwards, and

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* National Cyclopædia, Article 'Coal-Trade.'

either one or two seed-leaves upwards; the food of these seed-leaves was ready formed in the seed; through these roots and leaves carbonic acid is imbibed for the stem; but as we all know in the case of the turnip, if the seed-leaf is destroyed before the rough leaf is formed the plant dies: as soon as the stem and its leaves grow the plant sucks up water containing carbonic acid from the earth; this passes into the leaves, which are furnished with delicate mouths on the underside; through these little mouths, under the influence of heat, evaporation of the water takes place, and a still more peculiar influence of light causes the carbonic acid to be decomposed; the solid part, the carbon, is thus locked up or deposited in the leaf, the little mouths give out the pure air, to which we may now give its proper name, oxygen. Carbonic acid consists of carbon and oxygen; animals draw in oxygen, unite it to carbon, and breathe out carbonic acid. Plants do just the reverse, they draw in carbonic acid, decompose it, retain the carbon, and give out the oxygen; so is the balance of nature maintained.*

What is Ammonia?

Ammonia used to be best known by the name of volatile alkali: it is met with in the form of the liquid salvolatile, which is a solution of ammonia, just as a bottle of soda-water is often no more than common water charged with carbonic acid or fixed air; the ammonia itself is extremely volatile, and therefore it easily takes the form of a gas, and escapes unless kept closely corked up. It was originally made in Egypt from the droppings of camels, and derived its name from a district of that country

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* Dr. Daubeny has been kind enough to inform me that an elaborate memoir, on the composition of the air confined within the pores of vegetable mould, is published in the 'Annales de Chimie' for January, 1855, by Boussingault and Lewy, and to give me the following account of its results:—

"The conclusions deduced are interesting, inasmuch as they confirm the principle laid down by Liebig as to the consumption of oxygen and the substitution of carbonic acid, owing to the eremacausis or slow combustion going on in *humus*, and thus account for the fertilising influence of good mould upon the plants that grow in it. The proportion of carbonic acid amounted to from 0·66 to nearly 10·0 per cent., whereas the usual amount in atmospheric air does not probably exceed 1-2000th part. There was also a slight deficiency of oxygen besides what could be accounted for by the carbonic acid generated, and this probably was condensed on meeting with the hydrogen present in humus. There were also traces of ammonia in the vegetable mould. Recently manured soil contained the largest amount of carbonic acid; sandy soil often presents the least. It is easy to understand that so large a quantity of carbonic acid presented to the roots of a growing plant must exert a very considerable influence over its growth."

many centuries ago. In Europe it used to be made from horn, whence it derived the name of hartshorn; and it is now made in commerce by the distillation of all sorts of animal refuse. Large quantities are also made in the process of gas-making.* Such are the various sources from which the volatile alkali or ammonia of commerce is derived. It is combined (according to the process of manufacture) with various acids, which give the different names of carbonate of ammonia, sulphate of ammonia, and muriate of ammonia, which last is the same as salammoniac, the original Egyptian product. The form, however, of ammonia, which is at present most important to the farmer, is that which is to be found in the urine of animals. The urine is separated from the blood, and carries off all the waste of the muscular tissues which has been replaced by food. The solid excrements only carry off the undigested surplus matters which the system does not require to take up. Except, therefore, in the case of animals highly fed, little ammonia is formed in the solid matter of dung, but a great deal in the liquid. Lastly, wherever putrefaction takes place ammonia is formed, and from its volatile nature it immediately escapes into the air unless it is detained by some special arrangement for the purpose.

This ammonia, whether it is found in the form of a volatile gas, of a liquid solution, or of a solid crystalline salt, always contains that substance which is found in lean flesh, in cheese, and in gluten, and to which the name of azote or nitrogen is given. In 17 parts by weight of ammonia 14 parts are always nitrogen. From what has been said of putrefying bodies, and of the excrements of animals, it is obvious that a constant escape of ammonia must be going on, and therefore that there must be a certain quantity of it diffused through the atmosphere. For some time the amount of this substance in the air escaped all available chemical tests; but we owe its detection to the acuteness of Liebig.

Widely-varying accounts of the quantity of ammonia in the air have been given. The only estimate which I can find in Liebig's Agricultural Chemistry is merely an assumption. I am happy to be able to support this assertion by Dr. Daubeny's high authority, as it enables me to give the best information on the subject, in his words, from his recent lecture on Mr. Smith's mode of cultivation at Lois Weedon, delivered before the University of Oxford.†

* See the valuable information about gas-liquor in Professor Voelcker's paper on Manures, in the Journal of the Bath and West of England Society, vol. iii. p. 72.

† The lecture was printed at length in the 'Gardener's Chronicle' in the two last numbers, 51 and 52, for last year, 1854.

"Liebig's authority has been quoted in proof that every pint of rain-water contains one quarter of a grain of ammonia, according to which estimate it would follow that, as the average amount of rain which falls upon an acre of ground is not less than 5,096,520 lbs., no less than 166 lbs. of ammonia would be brought into contact with that breadth of soil in the course of a single year. But I do not find that this is anywhere absolutely affirmed to be the quantity present by the above-mentioned chemist, or that it is put forward by him excepting hypothetically; whilst undoubtedly the most recent experiments of Boussingault seem to show, that the largest quantity present in rain-water is 1 grain to 33 gallons; and that even in pump-water, when contaminated with animal impurities, not more than 1 grain to 2 gallons would be present, which is only half the quantity suggested by Liebig.

"With regard to rain-water, 1 grain of ammonia to 5 gallons,* or 40 lbs., was the proportion indicated by Boussingault's experiments, and consequently 16¾ lbs. only would be imparted to an acre of ground in a year by the rain which falls. To this, however, we ought of course to add the amount at all times floating in the atmosphere, which will be absorbed in greater or less abundance according to the nature of the soil, and here we must undoubtedly look for the advantage which certain soils derive from a careful subdivision, according to Mr. Smith's practice. The amount, indeed, actually present in the atmosphere is exceedingly small,† but nevertheless in the course of a year the quantity of air which is brought into contact with the soil is so enormous, that the difficulty of imagining the remaining portion to be thus absorbed becomes very much lessened."

The Elements of Water.

Having now ascertained that plants may derive a supply of carbon from carbonic acid, and of nitrogen from ammonia, and that both of these gases are diffused through the atmosphere, it may be well to state the intimate relation which water bears to carbonic acid and ammonia.

Carbonic acid consists of carbon in union with *oxygen;* ammonia consists of nitrogen or azote in union with another substance called *hydrogen.* It is remarkable that these two bodies,

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* "M. Marten, in the 'Ann. de Chimie' for this year, gives nearly the same proportions, viz. 0.003144 gr. per kilogramme of water."

† "The following statements are given of the proportion of ammonia in air; the enormous discrepancies show that little dependence can be placed on any:—1,000,000 kilogrammes of air, according to Gräger, a chemist of Mulhausen, contain 0·333 kilog. of ammonia; according to Kemp, an Irish chemist, 3·880 kilog.; according to Fresenius 0·098 by day, and 0·169 by night; whilst the recent experiments of M. Ville, which appear to have been conducted with great care, and by the aid of a most elaborate apparatus, make it much smaller; for in the years 1850 and 1851 the average was no more than 23·7 grammes in 1,000,000 kilog., or 0,000,000,0237 to 1, and in 1852 0,000,000,0210 to 1. Thus the several reports will stand as follows:—

In 1,000,000 parts—

Kemp's	3·8800 of ammonia
Gräger's	0·3330 „
Fresenius's	0·1690 by night
„	0·0980 by day
Ville's from	0·0237
to	0·0210."

oxygen and hydrogen, are the elements of water, united in the proportion of 8 lbs. of oxygen to 1 lb. of hydrogen, which, so combined, form 9 lbs. of pure water. You will not then wonder that water is capable of dissolving carbonic acid and ammonia. In fact, these gases diffused through the atmosphere are closely connected with the steam or vapour which the air contains; and when this vapour is condensed into clouds, and falls in rain, the water brings down from the heavens the substances which plants are chiefly made of, in the only state in which they are supposed to be capable of receiving nourishment into their circulation.* It is also deserving of your notice that water charged with carbonic acid or with ammonia has a power of dissolving some of the ingredients of the soil which are necessary to the existence and health of plants, thereby bringing them, as Dr. Daubeny has observed, from a dormant into an active state.

THE MINERAL MATTER OF PLANTS.

This brings us to the last part of plants, the mineral matter which they contain in addition to the elements already spoken of. The four elements of which we have spoken, namely, carbon, oxygen, nitrogen, and hydrogen, are called *organic* elements, because the organs, or regularly organized parts of plants, are chiefly composed of them; the mineral matter which remains after the organic matter has been burnt away, that is, converted back again into gases, this mineral matter is called the *inorganic* part, because the plant is then disorganised or reduced to its mineral elements, that is, to a shapeless heap of ashes.

The quantity of mineral matter, or ashes, to be found in the same part of the same species † of plant, does not vary much. For instance, there will be one proportion of ash in the grain of wheat, and another in the straw; and one proportion in barley grain, another in wheat grain; but neither the quantity nor the composition of the ashes in the different individual plants of each species will vary much. We also find certain kinds of mineral always present in certain plants in greater abundance than in others, *e. g.* potash in cabbage and potatoes, flint or silica in wheat-straw.

We are therefore justified in concluding that particular mine-

* Rain-water contains also an appreciable quantity of nitric acid, which is composed of nitrogen and oxygen; the bearing of nitric acid on agriculture is hinted at towards the close of this paper. But it would distract the attention of the practical reader from the main points to notice every particular. With the exception of the gases referred to, viz. carbonic acid, ammonia, nitric acid, rain-water is quite pure; but all spring-water contains earthy particles in solution, however clear it may look.

† See Lindley's Botany, p. 290.

rals are essential to particular plants, and that, if by a long course of cropping with the same plant we exhaust the soil of that essential mineral, the plant will not thrive. But of this more hereafter. Only let it be here observed, that we do not thereby prove that a full supply of all essential minerals will make a plant thrive, but only that it cannot do without them.

The chemistry of farming should explain the laws which regulate the supply of these minerals from the soil, and the conditions according to which the feeding or absorbing power acts in the plant.

The practical questions for the farmer to have answered are, which of these minerals he may safely rely upon his soil for supplying;—how he should manage the soil so that it may readily yield them up;—and what materials he must purchase and add in the form of manure.

The principal kinds of mineral food required by plants are potash, soda, lime, flint, phosphorus, and sulphur; and these minerals are found in the state of salts. In order to enter into the chemistry of agriculture it is desirable to have a clear idea of the general principles of salts; but it would interrupt us too much to go far into this subject at present. It will suffice to give a few instances. The mineral part of our bones consists chiefly of two remarkable salts—carbonate of lime, which is the same thing as common chalk or limestone before it is burnt, and phosphate of lime. If we analyse carbonate of lime we divide it into two parts, carbonic acid and pure lime, or quick-lime; we either drive out the carbonic acid in the kiln by heat, and leave the quick-lime, or we pour a strong acid on the limestone, which divorces the union between the lime and the carbonic acid, displaces the acid gas and joins itself to the lime, and so makes a new salt: this new salt will be sulphate of lime if we use sulphuric acid, and muriate of lime if we use muriatic acid. The phosphate of lime in plants is a salt formed by the union of phosphoric acid and lime. In like manner nitrate of soda is a salt, consisting of nitric acid and soda; gypsum is the salt already named, consisting of sulphuric acid and lime, called therefore sulphate of lime. Another instance of a salt is carbonate of ammonia, formed by the union of carbonic acid and ammonia, of which so much has been said.

There are two points to be especially noticed; 1st, that when an acid unites with a base, it ceases to have acid properties; and the base, which was an alkali, ceases to have alkaline properties. The properties of the salt are neither those of an acid nor those of an alkali, but distinct from both. For a common instance, we may take gypsum or plaster of Paris, which has not the caustic properties of either vitriol or quicklime, of which it is composed.

2nd. These properties of acids and bases neutralize each other in fixed proportions, and every acid and every alkali has its own proportionate value, which holds good in reference to every other substance in the world. 40 lbs. of sulphuric acid will balance 17 lbs. of ammonia, or 28 lbs. of lime, or 48 lbs. of potash. In like manner, 28 lbs. of lime will balance 22 lbs. of carbonic acid, or 36 lbs. of phosphoric acid: lime, potash, or soda will, in like manner, balance in certain fixed proportions any of the numerous vegetable acids to be found in plants, which are so important to us in food and in medicine; such as citric acid, tartaric acid in grapes, malic acid in apples. On the other hand, some of the most active principles of plants are vegetable alkalies; such, for instance, are quinine, morphine, strychnine (a dreadful poison), caffeine or theine, the principles of tea and coffee. These are all found in combination with various acids in the plants, and therefore exist in them as salts. On the understanding of this wonderful balance of nature depends the comprehension of the first principle of all decomposition, of fermentation, of manuring, and of the building up again of the fabric of the plant and of the animal. All nature around us has a tendency to restore its balance by the reunion of these conflicting elements: man is permitted for his own use to decompose the compounds of nature, and to make fresh compounds of his own; but if he leaves things to themselves Nature restores the balance in her own way. This is the true meaning of the common saying, that quick-lime has lost its nature when we have left it exposed to the air: the carbonic acid of the air has again united with the quick-lime, and brought it back to the state of mild lime.

So much, then, must suffice on this occasion on the theory of salts, and of their composition. But the practical consequences involved in the constitution of salts deserve a moment's attention. It follows that a great variety of changes may be going on in the soil and in the manures which we use. In most soils there is an abundant store of minerals which, if well managed, may be gradually made available to plants,—if ill managed, may be either locked up in an inert state, or washed away by rain. In like manner some of the elements of manure are volatile, and will soon escape in the absence of the precautions needed to fix them, that is, to retain them in a liquid or solid state. But the proper economy of these materials depends on a practical application of the properties of salts, which may be either volatile or fixed, either soluble or insoluble, according to the chemical proportions in which they may happen to be combined,* or to the circumstances under which they may be allowed to decompose.

* An illustration of this remark may be found in Dr. Bucknill's valuable paper on Compost Heaps, in the Journal of the Bath and West of England Society, vol. iii.

Let us now take a retrospect of what has been advanced.

Animals consist of three classes of substances: 1, of fatty matters containing no nitrogen; 2, of flesh, gelatine, hair, wool, &c., containing nitrogen; and 3, of mineral matters.

These substances are for the most part ready prepared in separate forms by vegetables for the food of animals.

The animals are constantly imbibing oxygen or vital air, and giving off carbonic acid and ammonia.*

The plant, on the other hand, imbibes carbonic acid, decomposes it, retains the carbon, and breathes out the oxygen under the influence of sunlight.

The plant also imbibes ammonia, decomposes it, retains the nitrogen, while the hydrogen unites with oxygen to form water, and that passes off by evaporation through the pores of the leaves.

The plant needs also a constant and definite supply of mineral matters, which it must derive from the soil; and if these mineral matters do not exist in the soil, they must be supplied in the form of manure.

But carbon in the form of carbonic acid, nitrogen in the form of ammonia, can be supplied from the atmosphere; and these substances can be absorbed as gases by the leaves, or as liquids by the roots when brought down by the rain.

Rain-water when charged with gases has a solvent power on the soil, and the soil has a special power of absorbing the gases.

We now touch upon a most delicate question on the confines of practice and science: namely, how far plants may be left to feed themselves from the soil and the atmosphere; and how far their food must be brought to them, and in what form. This will be dealt with in the second part of this paper. But first I wish to bring what has been said into one view in the diagram on the next page.

The diagram on the following page, like every other part of this paper, professes only to select the most salient and illustrative facts of the subject, without an exact or complete arrangement.

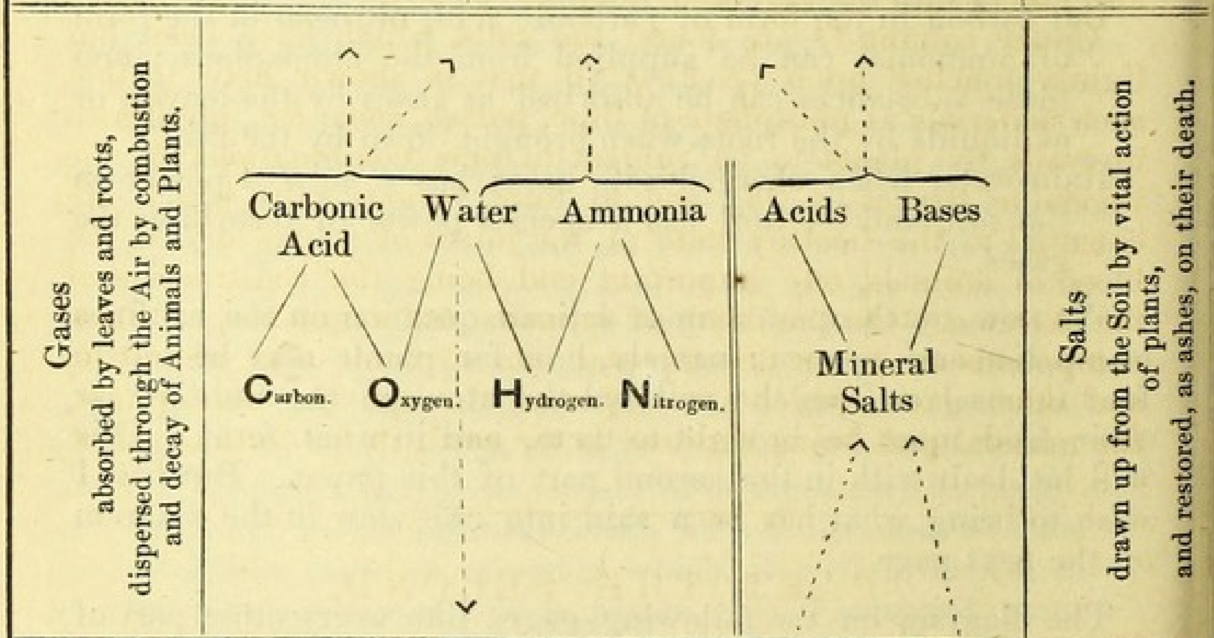
Our course has hitherto been to analyse common bodies of a compound nature into their less known elements. Let us now put together the elements as they are built up into compounds.

Beginning at the bottom of the diagram, the lowest compartment shows the action of the inorganic elements underground (p. 26). The next compartment above the lowest is intended

* "Among the infusoria there are some which exhale oxygen."—*Stockhardt's Principles of Chemistry*, p. 503.

DIAGRAM showing how the various Animal and Vegetable Compounds are built up from their Elements.

	Organic.		Inorganic.	
	A. Compounds requiring Carbon and Water only.	E. Compounds requiring Carbon, Water, and Nitrogen.	O. Compounds of Earthy Matter.	
Animal.	FAT.	FLESH and Gelatine.	BONE. Salts of Blood. —— Milk, &c.	
Animal and Vegetable.	Oil (Carbon and Water minus Oxygen).	Fibrine.* Casein.* Albumen.*	* Containing a little Phosphorus and Sulphur.	
Vegetable.	Sugar. Starch. Vegetable Acids. Woody Fibre.	Gluten.* Vegetable Alkalies, as Thein, &c.	Salts of Vegetable Acids, &c.	



Water Charged with Carbonic Acid and Ammonia filters through Soil,	Phosphorus, Potass, Sulphur, Magnesia, Lime, &c., are stored up in Soil,
dissolves Mineral Elements,	are pulverized by tillage,
Ammonia is absorbed by Clay.	are taken into solution by water.

to show what goes on in the air under the influence of light and heat, the relation between the organic elements, their descent into the soil in rain and dew, and the upward flow of both organic and inorganic elements in the sap of plants. The top of the diagram shows the products of organic life rising from those which are peculiar to vegetables to the highest organization in animals.

It must be understood that WATER pervades the whole process, collecting carbonic acid and ammonia, dissolving the soil, and carrying up again the salts (p. 25).

It will be observed, then, on the left-hand side, under column A, that carbon, oxygen, and hydrogen are alone required to form the simplest compound, viz. woody fibre, which, without any other addition, passes into various acids (p. 28), and also into starch and sugar (p. 19), till the oxygen is parted with and oil or fat formed (p. 15).

Under column E, nitrogen is the special agent, but it requires the aid of carbon on the one hand, and of phosphorus and sulphur on the other, to form the materials of flesh (p. 17). Nitrogen also enters into the vegetable alkalies (p. 28).

Under column O are found the salts, which have been but lightly touched upon (p. 27); all that is shown here is that such materials as phosphate of lime, potash, soda, &c., are drawn upwards by plants to be subject to new combinations in the vegetable tissues (p. 28), and to form various salts which are essential to the healthy state of the juices of plants and of the blood of animals, one important end being the construction of the skeleton. On the death of animals and vegetables all these compounds are again decomposed into carbonic acid, ammonia, and other gases, which are dispersed through the atmosphere, the mineral part being restored to the earth in the form of ashes.

PART THE SECOND.

WE may now proceed to show how the account which has been given of animals and plants applies to practical farming, and resume the question which the First Part concluded.

If it be really true that the great bulk of plants, their woody fibre or carbon, and also their nitrogen, so essential to the nutrition of animals, can be derived from the air, does not it follow that we have only to analyse the soil and find out what mineral matters are deficient, supply them, and leave air and rain and sun to do the rest? or, to state the question more definitely, is it practically true that, if we supply to plants the inorganic matters which we find them to require, they will supply themselves with the organic matters from the atmosphere?

Liebig answers boldly, in his 'Familiar Letters,' that "the produce of our fields will increase or diminish in a direct ratio with the supply of mineral elements capable of assimilation."* And again, "If an artificial supply of ammonia is not given, they can obtain all the required supply of nitrogen from the atmosphere."†

This is the famous mineral theory, most important if true; but the whole grand jury of English farmers, if they could be empanelled, would give its verdict "not proven."

Liebig is so confident in the truth of his theory, that he regards its practical application as merely a work of time.

"The problem in agriculture, at the present day, is no longer to seek for proofs of this truth, which no man of science doubts, but the grand object is to substitute for farm-yard manure that universal food of plants, its elements obtained from other and cheaper sources, retaining its full efficacy; and this can only be done when we shall have learned, what as yet we know but imperfectly, how to give to an artificial mixture of the individual ingredients the mechanical form and chemical qualities essential to their reception and to their nutritive action on the plant; for without this form they cannot perfectly supply the place of farm-yard manure. All our labours must be devoted to the attainment of this important object." ‡

I do not propose to detain you by discussing the theoretical arguments of the great chemist, I would only observe in passing, that even if we decline, with a smile, the advice of some of the professor's followers, that we should burn our dungheaps and apply only the ashes, let us not be too sure that the laugh will be all on our side. There are plenty of farmers now alive who laughed at guano, and thought they could never be brought to believe that a basketful of dust could do the work of a cartload of the old black stuff. It is impossible to predict what fruit principles fairly worked out may lead to some day; at any rate, farmers owe a great deal to Liebig for teaching the reasons for their own good farming, and putting them in the way to farm much more cheaply than their fathers did.

But we must bid farewell for the present to the illustrious German, and look at practice by the light of English chemistry, carried out on a large scale in the open field.

FARMERS NOT TO EXPECT TOO MUCH FROM CHEMISTRY.—WHY?

The practical questions which, I believe, many farmers want answered, are these—Can I find, by analysing plants, what food they want? and can I, by analysing my soil, find out in what it is deficient, and give my orders to my manure merchant accordingly, and so reduce my expenses and save the interest of my capital by buying only so much of each article as my plants may annually require?

* Liebig's Familiar Letters, p. 517. † Ibid., p. 518.

‡ Ibid., p. 481. I understand from Professor Voelcker that Professor Liebig has recently modified his views, and now attaches more importance to salts of ammonia and nitrogenised organic manures than he did formerly.

If these questions could be answered simply in the affirmative, farming would be reduced to a simple calculation, as sure as mathematics, and we might expect to see senior wranglers coming forth as first-rate farmers; or, at any rate, farming could be reduced to the same simple rules as any other manufacture. Now, not to mention the vicissitude of seasons, which affects all calculations of a business which has to be conducted in the open air, there are two reasons of a definite kind why the simple affirmative cannot be given to the farmer's questions above propounded.

1st. The difficulty of detecting, by chemical analysis of soils, the causes of their fertility. 2ndly. The imperfection of our knowledge as to the processes of life in plants, or as to what is called the physiology of plants. As to the first point, the analysis of soils, we know by practice that when a soil is what we call exhausted, if we attempt to grow a crop without manure it will not pay. We know also that the addition of say 3 cwt. of guano will, in many cases, make all the difference between a good and a bad crop. And yet, if a chemist were to analyse the soil before and after the application of the guano, it is very doubtful whether he would be able to detect its presence. For consider, an acre of soil, taken at the depth of an ordinary ploughing, cannot be estimated at less than* 1,500,000 lbs., allowing each cubic yard to weigh a ton; 3 cwt. of guano would contain (at 17 per cent.) about 50 lbs. of ammonia; the chemist therefore has to detect one part in 300,000, or the percentage of ammonia would be increased by 0·0003 by the dressing.†

This small percentage is practically far too minute for the most delicate modes of analysis to estimate with certainty for practical purposes. The same reasoning would apply to many of the other mineral elements removed by crops in small quantities. I wish to lay stress on this point, because I believe that some intelligent men, who desire to bring chemistry to bear on farming, have formed expectations from analysis of soils which can only lead to disappointment.

2ndly. As to the physiology of plants. Any one who has examined the modern books on Botany, such as those of Dr. Lindley for instance, cannot fail to be struck with the vast amount of minute and laborious investigation which has been bestowed by men of the very highest abilities and industry on every subject relating to the growth of plants. The scales of the

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* An acre contains 4840 square yards; therefore the soil to the depth of six inches will be a little more than 800 cubic yards. Allowing a cubic yard to weigh a ton, or say 2000 lbs., we have 1,600,000 lbs. of soil in an acre, without going beyond a depth of six inches.

† See Lawes and Gilbert in the Royal Agric. Jour., vol. xii., p. 3.

chemist, and the microscope of the botanist, vie with each other in aiding the search into the wonderful workings of life; and yet one cannot but feel how very little is absolutely known of the state in which plants take their food, and of the way in which they assimilate it. Still more must we admit how little we are able to estimate and explain the circumstances which regulate the development of each part of the plant; the practical experience and ingenuity of the gardener have far outstripped the theory which tries to account for his acts, and just so it is in farming. We want different plants for the sake of different parts, corn crops for their seed, forage crops for their leaf, and the turnip for its root: and to a certain extent we have found the means of turning the laws of nature to our account; but of the agencies by which the living plant prepares for us our corn, our grass, and roots, we know little; and therefore how to obtain more grain, how to stiffen the straw, by what management we can avert the smut, the rust, and the mildew, are questions which all practical men ask, but the man who knows most about science is slow to give a positive answer, and the reason is the imperfection of our knowledge as to the food and growth of plants.

For these two reasons, then, the imperfect powers of analysis and imperfect knowledge of the laws of living things, we cannot at present reduce farming to the simple question of supplying to plants what they take out of the soil.

It is not, however, by any means useless to ask what is removed from the soil in the ordinary course of farming. And to this subject let us next turn our attentive consideration.

WHAT DO CROPS REMOVE FROM THE LAND?

The gross weight of vegetable produce raised on an acre of good land managed on the four-course system, will be, in the course of four years, about 40 tons in round numbers, of which about fourth-fifths will be water; leaving, in round numbers, about 19,000 lbs., or say 8 tons, of organic .matter, and about 1300 lbs. of inorganic matter or ashes, which would be left if all the crops of the four seasons were burnt. Let us look at these materials a little more in detail, but without going into any more particulars than will serve to give a practical illustration of the question of manures. The organic matter, as you will remember, is that which is capable of being burnt away, of which carbon and nitrogen were the two parts which most engaged our attention. It was asserted that they were united with the elements of water in carbonic acid and ammonia, and in those forms imbibed by the plant.

The four years' crop will be found to contain about 9000 lbs.

of carbon and about 3 cwt. of nitrogen. The carbon is about equally divided between the corn crops and the green crops, but the nitrogen is divided in the proportion of 1 cwt. to the corn crops and 2 cwt. to the roots and grass. I beg your particular attention to this fact; you will see presently that it leads to a practical conclusion exactly the reverse of what you would expect.

Now let us look at the mineral constituents. Is it not at first sight a surprising fact that the whole of that part of four years' crops which is not combustible should amount to less than one cart-load of ashes? Of these mineral elements I will only mention a few which are supposed to be most important in manure. Foremost of all come phosphate of lime and potash, because they are often scarce in soils of average quality. Moreover, the amount of potash required by plants is considerable, and it is a very expensive mineral to purchase as a separate article of commerce. Flint or silica is essential to the stalk of wheat, being that on which its stiffness depends. The other elements, such as soda, magnesia, iron, sulphur, and common salt, are either insignificant in point of amount, or are generally found in average soils in sufficient quantities.

The four years' crops will contain, then, about 100 lbs. of phosphoric acid, or 2 cwt. of phosphate of lime, about 3 cwt. of potash, which, together with about 2 cwt. of lime, and between 2 and 3 cwt. of sand and silica, will account for more than two-thirds of the whole of the mineral matter. I beg you also to observe that the turnip crop only contains about one-fourth part of the phosphate of lime; the grain of the wheat and barley containing nearly half of it. It may be well to mention in passing that if we had taken other root crops instead of turnips there would have been a difference in the proportion of some of the elements. For instance: mangold would have increased the amount of salt; potatoes, carrots, and parsnips, require a large amount of potash; the two last rather increase the percentage of lime.

So much of these facts as bears on the question of practical manuring is set forth in the following Table, which is prepared from various sources, but chiefly from Mr. Heming's Tables in the Royal Agricultural Society's Journal, No. xxx. p. 435, &c. Round numbers are in all cases taken, and some are assumed, the only intention being to bring under one view a rough division of the constituents of crops, for the purpose of showing,—1, how much is obtained from the atmosphere; 2, how much is lost in breath of animals; and 3, how little of the mineral matter is carried off the land.

TABLE IV.—Showing the Total Weight in lbs. of Crops raised in Four Years on an Acre of good land, and *some* of the most important of their constituents (omitting others).

	Total Weight of Fresh Crops.	Water.	Total Dry Matter. exclusive of Ash.	Organic Matter.		Inorganic Matter.		Total Ash.
				Carbon.	Nitrogen.	Phosph. Acid.	Potash.	
Wheat 32 bushels. . . .	2,000	250	1,710	800	42	20	10	40
Straw 30 cwt. and chaff .	3,750	450	3,100	1,500	10	5	16	200
Barley 48 bushels . . .	2,500	300	2,140	1,000	40	20	10	60
Straw, &c.	3,350	500	2,650	1,300	8	6	6	200
					About 100			
Roots—								
Bulb 20 tons	45,000	41,300	3,400	1,700	75	26	116	300
Tops 8 tons	18,000	15,500	2,300	1,000	90	10	18	200
Grass 6 tons	15,000	11,000	3,700	1,700	70	20	70	300
					About 240			
Nearly	90,000	70,000	19,000	9,000	350	107	246	1,300

The next point to be examined is, what portion of the crops is removed from the farm, and what is returned to the soil in the usual course of good farming.*

In the first place, the grain crops take off about one-fourth part of the carbon, about 80 lbs. of nitrogen, and about 50 lbs. of phosphoric acid, or 1 cwt. of phosphate of lime; what they take besides is practically insignificant.

Another part of the produce that goes to market is the live stock or dead meat. The carbon contained in a few score of meat is not worth calculating; the nitrogen is only about 1 lb. to the score sold off, and the phosphates about half the weight of the bones of the animals:† say about 35 lbs. for the whole of the

* The reader will not fail to observe that I speak of "good land" and "good farming."

† The amount in the text is arrived at thus: I assume that 10 sheep would be kept twenty weeks on turnips, and that they would require for the rest of the year an acre of pasture or meadow-land in addition to an acre in clover. Without artificial food, I think they would not on the average go to market under two years old. If we give the meadow credit for 1 sheep in 5, we have 4 sheep to put to the account of the turnips and clover, or 60 lbs. of bone, which would require about 30 lbs. of phosphate of lime for the stock sent off an acre in four years, or about 7 or 8 per acre annually. I assume the bones of a sheep to weigh 15 lbs.; and as all accurate records of facts have their value, I venture to quote the following note from the Report on the Farming of Somerset as my authority:—

"I have found great difficulty in ascertaining the weight of the bones of cattle and sheep. I could not obtain the information from the butchers or from any book. At last a Somersetshire friend in the College of Surgeons, Mr. Quekett [the distinguished microscopist], ascertained from the sausage-makers that the bones of a short-horn bull, aged seven years, weighed 138 lbs.; those of a half-bred Southdown ram, 15½ lbs.: the bones of younger animals would doubtless weigh less. I have since met with some information on the subject in Morton's 'Cyclopædia,' article 'Bone Manure.'"

stock fed on one acre of land, in the course of 4 years. In the case of dairy farms or breeding farms, the quantity of phosphates yearly carried off in cheese and in bones of animals reared on the farm is greater than on arable farms; but a little bone-dust will supply the deficiency.

Those who have not attended to chemistry will feel some surprise when I state that, though the live stock do not carry much carbon to market on their frames, they have consumed—that is, fairly burnt away—in their lungs during their lives about half of all the carbon contained in the roots and grass which they have eaten.* The mineral matters contained in their food pass through into their dung practically undiminished, with the exception of the phosphate laid up in their bones. To the carbon sent to the miller in the sack we must therefore add about a ton of carbon blown to the winds, and perhaps helping, as part of the air, to drive the sails of the windmill, or tumbling over the wheel in the water which, after falling on the hills as rain, is on its way to the ocean, there to be converted into food of sea-weeds.

The account then stands thus in round numbers:—

		Returned to the Farm.
Phosphates		1 cwt.
Nitrogen		2¼ „
Carbon		over 2 tons.
The carbon represents fresh vegetable matter:—		
In straw	7,000 lbs.	over 24 tons.
Fodder passed through animals as dung .	30,000 „	
Leaves trodden in .	18,000	
	55,000	

		Removed from the Farm.
Phosphates		1 cwt.
Nitrogen		1¾ „
Carbon		under 2 tons.
The carbon represents fresh vegetable matter:—		
In grain	4,500 lbs.	under 16 tons.
Fodder consumed in breath . . .	30,000 „	
	34,500	

The practical result of this analysis of the four-course system is that about one-half the carbon of the crops regularly leaves the farm, together with about a cwt. of nitrogen and of phosphate respectively. This quantity of carbon represents no less an amount of vegetable matter in its fresh state than 15 or 16 tons, which, not having been returned in the form of manure, and not existing in the soil in an ordinary state of condition,

* This calculation is arrived at thus:—Boussingault ascertained by careful experiment that a cow consumed rather more than 70 oz. of carbon, which would amount in 20 weeks to 612 lbs. The amount of carbon in roots is about half the dry organic matter, and this again is about one-tenth of the whole weight of the roots; so that the weight of roots required to supply the carbon consumed in the breath would be above 12,000 lbs., or nearly 5 tons. Two bullocks eating about 1½ cwt. of roots each per day would consume 20 tons (the produce assumed per acre) in 20 weeks; of which 10 tons would have passed off in the carbonic acid of the breath. The estimate for grass would not be very different.

A ton of oil-cake contains about 1 cwt. of nitrogen, and half a cwt. each of phosphoric acid and potash. Therefore, if half a ton of oil-cake is consumed with every acre of turnips (no extravagant supposition), the whole of the nitrogen and of the important minerals in the corn crop will be restored in the cake alone, supposing that there were no other source of supply.

must have been exclusively derived from the atmosphere. How the nitrogen and the phosphate are replaced we will inquire presently; but, as a comment on the mineral theory above referred to, it is a remarkable fact that, under the best system of English farming, not only is the greater part of the mineral constituents of plants left on the farm, but a considerable addition is made to them in the form of purchased food. It should also be observed that I have not taken into account the corn which is consumed by horses or given to stock on the farm.

HOW ARE THE ELEMENTS OF THE CROPS TO BE REPLACED?

One conclusion I think you will at once see follows from what has been said, viz. that however valuable farmyard-dung may be, it is hopeless for the farmer to attempt to replace in the form of straw-manure all the vegetable matter which the usual course of farming removes from the land, seeing that by an inevitable law of nature several tons of vegetable matter must every year be consumed and turned into gas by the feeding of stock, unless you should think it profitable to plough in all your green crops instead of consuming them by live stock. We must therefore look further to ascertain the true reasons for applying manures and the principles on which they are to be selected.

WHY IS FARMYARD DUNG SO VALUABLE?

As regards farmyard-dung its value probably consists in several points. 1. That it presents a great choice of salts of all sorts in every state of combination, and in every digestible form, so that the plant finds all its wants easily supplied: well-made dung is always rich in ammonia, phosphates, and potash, which, as we have seen, are the elements of prime necessity. 2. It acts mechanically on the soil by loosening clay and binding light soils. 3. Its slow fermentation no doubt raises the temperature of the soil. And lastly, as it ferments and decomposes, it probably supplies carbonic acid to the roots of the plants, and so assists the action of the atmosphere and the rain, both in directly supplying carbon, and in dissolving the alkalies and other minerals in the soil. The objection to dung as the sole supply of the farm is, that it is expensive to make, bulky to move, and always insufficient in quantity; and on these accounts the chemist and the farmer have both done their best to find some cheaper means of keeping up the fertility of the soil and the supply of the food of the people.

WHAT IS GUANO?

There is hardly any fact in the history of agriculture which so impresses my mind with the sense of an overruling Providence as the introduction of guano into this country at the time when opposite classes were engaged in a struggle on the question, how are the people to be fed and how is the tiller of the soil to live?

For consider what guano is. In the crowded cities of old countries like England we annually consume an enormous amount of corn and meat, of which nearly the whole of the nitrogen and phosphates pass off into the sewers, from which as yet the wit of man, not to mention the wit of Mechi, has utterly failed to recover them: down they flow to the rivers and thence to the ocean, there as it might seem to be hopelessly lost. But stay, consider how the ceaseless motion of the sea diffuses these elements all over the globe, how the great forests of seaweed, feeding on the carbonic acid in solution, bring up the stores from the depth, how the fish feed on what floats in the water, and how the seafowl again, subsisting partly on the seaweed and partly on the fish and the animalcules attaching to the weeds, deposit their droppings on rocks in a rainless region, where the manure being quickly dried never ferments, and so by a wonderful provision of the Great Creator, we are permitted to go down to the sea in ships and bring back the materials of our food which our rivers had washed away. I refer to this fact not merely because in guano we have a supply of ammonia in a cheaper form (even at present prices) than any other in which manufactures or commerce can at present bring it into the market, but because I think guano has been the great practical schoolmaster of the English farmer. Our illustrious countryman Sir H. Davy discovered and expounded in his admirable lectures the theory of ammonia as a source of food to plants; but his lectures bore little fruit till we had the great practical proof that a man could draw into a 10-acre field in a single cart the essential ingredients of fertility which he could not formerly obtain without a hundred journeys of his waggon.

It being now an admitted fact that light and portable manures are indispensable to economical farming, the labours of our chemists have been urged on, not only by their own thirst for knowledge but by the general recognition of their utility, to discover what elements each crop requires, and from what sources these elements can be most cheaply supplied.

English Chemistry of Farming.

Claiming as we certainly may for our illustrious countryman Davy the honour of leading the way in the application of chemistry to agriculture, we must admit that since his day great progress has been made in France, and that Germany may well be proud of Liebig, not only as a most profound chemist, but also as having done much to awaken attention to agricultural improvement, and to engage in the service of agriculture some of the most eminent men of science. But it has been reserved for a country gentleman, by a systematic course of field experiments, to bring, for the first time, the facts of practical farming, as carried on in England, to the test of scientific accuracy. For half a century * *The Art of Farming* and the *Science of Physiology* had made separate and unconnected progress, but they were frequently at variance. Mr. Lawes of Rothamsted, aided by Dr. Gilbert (a chemist trained, I believe, under Liebig, and certainly a most competent scientific assessor), has succeeded in bringing principles discovered in the laboratory by the great French and German chemists into direct and close application to our eminently practical art; and it must never be forgotten how much England owes to another country gentleman, Mr. Pusey, whose accumulation of the practical knowledge of all England, in the Journal of the Royal Agricultural Society, edited by him for fifteen consecutive years, has furnished a constant check to hasty and premature conclusions suggested by scientific discoveries.

Experiments of Mr. Lawes and Dr. Gilbert.

I will now endeavour to set before you very shortly some of the principles established by Mr. Lawes and published by him to the world in 1847, after several years spent in a course of experiments which stand unrivalled in the History of Agricultural Science, for the scale on which they were conducted, without sacrifice of rigidly strict accuracy.

It is, however, due to Mr. Lawes and Dr. Gilbert that I should state that they are in no way answerable for the accuracy of this account of their experiments made more than seven years ago—in fact, it was prepared without their knowledge, and chiefly from their earlier papers. Those papers have been the subject of most searching discussion, and I am not able to say that subsequent investigation may not have modified some of the first results of the Rothamsted inquiries. My chief object has been to sketch a bold outline, and to impress upon the minds of some of the rising generation the amount of labour necessary for gaining an accurate knowledge of even one or two points of agricultural science.

The two practical conclusions to which these experiments lead are these: 1. That in order to increase your crop of wheat you must give the plant an artificial supply of ammonia; and 2. That in order to grow turnips at all you must add a special supply of phosphate of lime. I mention these two practical

* The Bath Society was founded 1777. Sir H. Davy began to lecture on Agricultural Chemistry in 1802.

results at once that you may bear them in mind while you hear an outline of the course of inquiry by which Mr. Lawes arrived at them.

The great progress made by chemistry since Davy's time rests for its basis of proof on the gradual accumulation of analyses of animal and vegetable produce by German and French chemists, and more recently by Way, Gilbert, Johnston, and others in England, among whom we must not forget our own Dr. Voelcker. But I have more than once hinted at the caution, that we must not hastily assume the percentage of any particular constituent found in a crop to be a safe guide to the kind of manure which must be applied in practical agriculture.

Peculiarity of Cultivated Plants.

The reason why some persons have drawn this inference too hastily is this, that they have not sufficiently borne in mind the distinction between the requirements of plants in a state of nature and those of plants cultivated for special purposes on ground limited in space, and under circumstances in which profit or loss depends both on making the most of the space and on not wasting time. With regard to all crops it must be remembered that the whole plant is not equally important to the farmer. In cereal and leguminous crops what we want is the seed, in turnips and mangold-wurzel the roots, in others only the leaf and stem: to these parts respectively we wish to give the greatest development consistent with the general health of the plant. The principles which explain how large forests thrive on mountains, or even how a few crops may be rapidly raised on virgin soils, are no safe guide to the regular course of cultivation which must be adopted in an old country like England. Liebig appears not to have sufficiently attended to this distinction; and finding that trees and plants derive, under certain circumstances, all their ammonia from the atmosphere, he was led to give his exclusive attention to the supply of mineral elements of manure, and to advise the farmer to dispense with all artificial supply of ammonia. We shall see how this fails in the case of corn crops.

Importance of particular Organs of Plants.

Another principle appears very important in the growth of plants, viz. that some elements are required in certain stages of the plant in order to develop particular organs to an extent far beyond that which would be indicated by the analysis of the full-grown plant. It appears that the plump, full quality of the grain of wheat depends not upon its richness in gluten (the nitrogenous or flesh-forming compound, and therefore the most nutritious to the working-man), but on the abundance of starch, in which there is no nitrogen, and yet that the elaboration of this starch depends to a great extent on an abundant supply of ammonia ;* this ammonia seems to be required to foster the growth of the leaf and stem, and generally to promote vigour in the circulation of the plant; but the quantity of nitrogen eventually found in the crop would not correspond with that required in the earlier stages of the plant's existence. In turnips, on the other hand, it seems equally important to the development of the young roots, and to the early childhood, so to speak, of the turnip, that it should be supplied with phosphate of lime in a state of delicate solution, like the pap supplied to the infant; but the percentage of phosphate of lime in a crop of turnips is, as we have seen, not so large as that of the same mineral in a crop of wheat or barley. I remember very well the strong impression of disappointment under which, when superphosphate of lime was first talked about, I searched in books for evidence of the opinion that turnips required a liberal supply of phosphate of lime, on account of the proportion of that substance in the plant as shown by analysis. In fact, analysis taken by itself does not lead to this conclusion, but requires to be combined with other considerations derived from practical experience.

EFFECT OF CLIMATE.

There is a third principle which governs all chemical inquiry into the growth of plants, and that is the effect of climate ; and by climate is to be understood the variations of the amount of rain, and of the time during which rain falls on any spot ; also the variations of heat and cold, both as to the general average, and as to the highest point of heat in the summer, and the lowest point of cold in the winter. This is a point of special importance to the West of England farmer, because our climate has certain special characteristics of its own ; and, fortunately for us, one of the very best and most zealous inquirers into this subject is a West of England man, Mr. Whitley of Truro. It seems that, in certain seasons, the effect of climate is greater than that of manure ; so that, according to the old proverb, seasons beat judgment. A well-manured piece of land may sometimes fare worse than another which has been only cleaned and left to nature. The importance of rain or of sun at certain particular seasons is well known to the practical farmer. The absence of rain during the time when plants are forming their leaves, or cool weather while the seed is being filled, will modify all the farmer's calculations, and must, in like manner, be taken into account by the

* I am informed by a high botanical and chemical authority that it would be more correct to say that the elaboration of gluten depends on the presence of ammonia, and that of starch upon the gluten.

agricultural chemist. Mr. Lawes tested the power of the soil to produce crops without manure, as a means of judging of the effect of atmospheric influences alone; and he found that the lowest weight of the bushel, and the greatest amount of straw, corresponded with the season in which there were the lowest summer heat and the greatest number of rainy days; the least amount of straw corresponded with the driest season, and the finest quality of grain with the hottest summer. He also found that the effect of season on a great number of plots treated with various kinds of manure corresponded with that upon the unmanured spots. All these facts he has minutely registered and compared, and they lead to the conclusion that no variation in the quality of manures will enable the farmer to overcome the effect of climate, but that something may be done by a careful study of the laws of atmospheric action to adapt the management of the land to the conditions under which it is placed, and so to take advantage of what is favourable, and to avoid what is the reverse.

We are indebted, then, to Mr. Lawes for giving scientific accuracy to the common observation and experience of the farmer on these three points. 1. The difference between the conditions required by a cultivated vegetable on a farm, and those of a wild plant. 2. The great importance of examining the functions of separate organs of the plant, and adapting the treatment accordingly. 3. The extent to which all calculations as to the effect of manures must be modified by considerations of climate.

Experiments on Wheat and Turnips.

Bearing these three points in mind, let us hear what Mr. Lawes has to tell us about wheat and turnips, and what is the nature of the evidence on which his opinions rest.

His laboratory has two departments, one in-doors and one out of doors. The first is a large barn, in which his analyses take place, of the scale of which perhaps I can best give you an idea when I say that the platinum capsules—pieces of apparatus which in an ordinary laboratory are about the size of very minute saucers—are, in Mr. Lawes's case, about the size of tea-trays, involving a hot-water drying apparatus for evaporations, and other appliances on a proportionate scale. The second department of his laboratory consists of two or three 14-acre fields, divided into half-acre pieces. The whole of the crops grown on these plots for several years were separately weighed, and samples sorted and laid up for analyses. Besides the experiments on these crops, another and a very extensive series of investigations into the feeding of sheep and pigs has been carried on for several years, involving the weekly weighing for 6 months not only of 20 or 30 animals, but of their food and their excrements, and the subsequent analysis of the same.

Mr. Lawes's Experiments on Wheat.—One great value of Mr. Lawes's experiments is that they were tried, not in artificial garden soil, but in an ordinary field, at the end of a course of practical cropping, and therefore in that state which a farmer considers practically worked out as far as manure is concerned. One portion of this land has been preserved, year after year, in its natural state, as a permanent standard for comparison with each kind of manure. Side by side with this unmanured spot he has tilled wheat and turnips on about twenty-four strips of land with as many different combinations of mineral manures. These strips were crossed again with the manures containing ammonia and carbon.

One remarkable fact is elicited by the unmanured spot, that a certain amount of wheat may be grown, year after year, without the addition of any manure whatever, and that this amount will not vary greatly in the same soil. In the case of Mr. Lawes's land the amount was about 16 bushels, and 10 cwt. of straw.

1. The first point established is that *mere mineral manures*, such as are found in the ashes of plants, *will not increase the yield of wheat without the addition of ammonia.* Various combinations of potash, soda, magnesia, lime, as phosphates and silicates, were tried, and the greatest increase obtained was 2 bushels of wheat and 84 lbs. of straw; and to put the matter to the strongest test, the ashes of 14 tons of dung were tried without any increase of the natural produce.

2. *The addition of ammonia to some of the mineral manures produced an immediate rise in the produce*, varying from 4½ to 9 bushels of wheat, and from 2 to 5 cwt. of straw. The same effect was even more striking when the addition of ammonia was made, in the second year, to the spots where it had not been applied in the first year, but on which minerals had been applied without any good result. It now produced a great increase of crop, showing that the mineral manures had been lying dormant for want of the ammonia. Liebig's patent manure was treated in like manner; when applied alone it yielded insignificant results; when applied with the addition of a salt of ammonia, an increase of 14 bushels of wheat and 10 cwt. of straw ensued.

These experiments, extending as they did over 50 spots of land during several successive seasons, and also brought to the test of the scales, are generally considered to have given decisive proof of the principle that the natural produce of wheat cannot be increased without an extraneous supply of nitrogen or ammonia. And Mr. Lawes states it as his opinion that every bushel of wheat, containing in itself about 1 lb. of nitrogen, requires 5 lbs. of ammonia for its production, instead of $1\frac{1}{4}$ lb., which would contain 1 lb. of nitrogen. If this be so, the wheat-plant is a great waster of ammonia, and some good chemical reasons have been assigned by Professor Way for this consumption of ammonia, which are very interesting in a scientific point of view. At any rate, the principle laid down by Mr. Lawes is in harmony with the experience of the farmer as to the exhausting character of the wheat-crop if too frequently repeated without rich manure, and as to the power of bare fallows on clay to ensure a crop of wheat up to a certain average. With regard to the means by which ammonia is to be replaced, it is needless to suggest that every step should be taken to assist the soil in collecting the lost ammonia from the atmosphere, and therefore to that extent to save the farmer the expense of purchasing so expensive an article. It was for this reason that the naked fallow was invented; that lime is applied to clay; that underground-draining and subsoil-ploughing are found so beneficial on heavy land. But in order to explain how the ammonia is restored in the most practical manner by a rotation of crops we must pass on to Mr. Lawes's experiments on turnips.

Mr. Lawes' Experiments on Turnips.—The turnip is in all its habits opposite to the wheat-plant, and its cultivation in modern farming is in the highest degree artificial. It is sown out of season on purpose that its seed may not ripen, and that an unnatural development may be given to one organ—the bulb. The consequence is, that peculiar conditions in the soil and in the atmosphere, and a peculiar supply of manure are required, in order to secure not merely a good crop, but any crop at all.

In Mr. Lawes' experimental field the unmanured plot produced in the first year but 4 tons, which, in the third year, dropped to 13 cwt., and the roots had dwindled down to the size of radishes. In this respect, then, turnips differ from wheat; and although they derive a much larger portion of their substance from the atmosphere, they are more absolutely dependent on manure of some sort. The question to be ascertained is, What is the particular quality or substance in manure which the practical farmer has to supply? As turnips contain so large a percentage of nitrogen, which, as we have seen, is obtained in the form of ammonia, it is natural to suppose that a liberal dressing of ammonia is to be supplied by artificial means; and this idea is at first sight favoured by the experience of those who are in the habit of applying all the dung they can make to their root-crops with success. And some farmers I know are of opinion that the ammonia of guano is valuable as a support to the turnip in the later stages of its growth. Mr. Lawes' experiments point to a somewhat different conclusion; in fact, they prove that an excess of ammonia is very injurious to the turnip, because it promotes an excessive development of leaf with a decreased proportion of weight in the bulb. This is shown by the mean results of many experiments with compounded manures; but the following instance will put the principle in a striking light. Twelve tons of farmyard dung produced 17 tons per acre of bulb and 7 tons of leaf. The same quantity of dung, with the addition of a salt of ammonia, produced less than 15 tons of bulb, but 10 tons of leaf, showing an increase of 3 tons of leaf at the cost of 2 tons of bulb. Ammonia then, is not the specific for turnips.

There are some facts which show that the proportion of nitrogen in a crop of turnips may be increased by a supply of ammoniacal manure, but I think they do not practically affect the position, because the percentage of nitrogen is by no means the test of the profitableness of the crop.

Space will not permit me to go through Mr. Lawes' experiments in any detail, but the result may be stated thus:—That, however favourable the season may be to the growth of turnips, a crop cannot be obtained without a supply of certain minerals. That the mineral chiefly required is phosphate of lime, and that that must be supplied in a finely divided or dissolved state. That this mineral supply will not avail to carry the crop on to full maturity without a supply of carbonaceous matter, such as that of straw-dung or rape-cake, unless the land is already in good condition, that is, rich in vegetable matter in a state of decomposition.

Mr. Lawes has also shown by detailed experiments that in considering the effect of manures, especially in the case of root-crops, we are not to consider merely the constituent parts of the crop, but the healthy action of the organs of the plant. And it appears that the importance of superphosphate of lime is connected with this principle. This mineral seems essential to the healthy underground development of the net-work of roots: without a supply, therefore, of this material the plant never gets a start. A certain amount of ammoniacal manure conduces to the expansion of the leaf, which seems to be the apparatus provided by nature for collecting both carbon and ammonia from the atmosphere: I say provided by nature because a further and more artificial process has to be performed late in the season, namely, the excessive and preternatural development of the bulb. This appears to be especially promoted by the early development of the fibres of the root caused by superphosphate, and now comes into play the store of carbon laid up in the soil in the form of farmyard-dung or other organic manures.

This view of the subject is, no doubt, to a certain extent hypothetical and beyond the reach of positive proof; but the facts appear plain: that the entire omission of phosphates is fatal to the development of the plant; that the excess of organic manures, such as guano, &c., is dangerous; and that a full development of bulb is never attained where there is not an accumulation of carbon* in the soil or where it is not added as manure.

Practical Conclusions.

One or two practical conclusions from the facts just stated may be added.

That the tilth, to which all farmers attach so much importance, is essential to the early development of the fibres of the root. That the mineral manures (superphosphate) should be placed in close contact with the seed. That organic manures should be sown broadcast and widely mixed with the soil, so that the extensive apparatus of fibrous roots may find food everywhere while they are sustaining the bulb after the leaf has passed its most active stage. It would also seem that an opinion expressed in one of the excellent papers on root-crops in our volume of last year, that roots may be as well grown on the tops of our hills without dung as with it, requires some modification, namely, that on thoroughly poor land this should not be attempted at first, unless indeed a long accumulation of weeds may be supposed to supply the vegetable matter required; when the land has been effectually cleaned, and a good crop fed off on the ground, the case becomes altered. Where the dung-heap is far off at the bottom of the hill, Mr. Lawes' experiments show that a few cwt. of rape-cake will play the part of several tons of stable-dung with good effect.

* On further inquiry it is right to state, that on the carbon question Mr. Lawes' experiments are not quite decisive. The rape-cake which he used as carbonaceous food for the plant contains other elements, *e. g.* potash and phosphates, to which some of the effect may be due. It is characteristic of Mr. Pusey's practical judgment, that, in his Summary of Agricultural Progress, republished in our first volume, he speaks cautiously on this subject.—See Journal of the Bath and West of England Society, vol. i. p. 73. I may take the liberty of suggesting to any young farmer who has had patience to accompany me thus far, that, if he is not chemistry-sick by this time, he would do well to turn to our first volume and read the whole of Mr. Pusey's remarks carefully. Had I refreshed my memory by a re-perusal of that masterly Summary before I wrote this paper, perhaps I might have saved the printer and the reader some trouble. It will not escape the attentive reader that hitherto turnips have been chiefly spoken of, and that in what follows fallow-crops generally are named. Mr. Lawes has shown in later papers that plants of the leguminous tribe, clovers, beans, &c., are the great collectors of nitrogen; but I did not wish to divert attention from the evidence of the different practical requirements of corn and roots in the way of manure—corn requiring nitrogen, roots requiring phosphates.

GENERAL SUMMARY.

We may now look back at the general light thrown by these experiments on the common operations of the farm in connection with the chemical composition of plants referred to in the earlier portion of this paper.

Wheat, though it contains a small percentage of nitrogen, is the great consumer of ammonia, and therefore of nitrogen. Fallow crops are the great collectors of nitrogen from the air. Turnips require a constant supply of certain minerals, and probably of vegetable matter or carbon, in order to produce large bulbs. It only remains for the farmer to ascertain in what way he can most cheaply, and at the same time most effectually, supply his corn crops with nitrogen, and his turnip crops with minerals and carbon. The answer is not difficult.

For here again, as has often been the case before, practice has been beforehand with science: the farmer has found out practically that to consume his roots on his land whenever he can, and to add purchased food at the same time, is both a wise economy and a source of profit.

The reason is now discovered. The fallow crops collect ammonia or nitrogen from the air, and the stock in eating them return a very large proportion of the nitrogen to the soil in their dung, if it is properly taken care of. It would not be difficult also to show how the improvements in the breeding of animals, and especially the increased consumption of artificial food by good farmers, all tend to the same result—the rapid conversion of the green crops into a higher description of food, fetching a higher price in the market and yet leaving behind in the soil that part of the green crop which is most valuable as a means of reproducing corn, viz. the nitrogen ; while the straw of the corn is being converted into precisely that kind of food which tends to feed a future crop of bulbs. The practice then of our highest farmers, who put dung on their clovers, is strictly consistent with all that science can teach at present: the dung not only stimulates the clover crop, which is a great collector of ammonia,* but the ammoniacal salts in the dung saturate the soil with the appropriate food of the wheat crop, while the straw is first decomposed on the surface, and afterwards intimately mixed with the soil. A store of vegetable matter is thus laid up to feed the ensuing

* The grounds for the assertion that the leguminous crops are the great collectors of nitrogen may be found in the article on Liebig's Mineral Theory, by Mr. Lawes and Dr. Gilbert, Royal Agricultural Society's Journal, vol. xii. pp. 29-32.

root-crop, which then requires little but superphosphate of lime and good tilth to call it into vigorous existence.

With regard, then, to an artificial supply of mineral manures, it is certain that phosphate of lime must in all ordinary farming be purchased year by year, seeing that it is necessary not only to find a sufficient amount of phosphates in the soil, but also to apply them close to the seed of the turnip in a certain chemical and mechanical state. As a matter of economy, it is worth while to remark that the phosphate of lime to be found in one ton of well-made superphosphate, at 7*l.* 10*s.*, is more valuable than that in two tons of guano, costing three times as much.

On the other hand, the supply of nitrogen may be obtained either as already explained through the green crops and artificial food, or it may be purchased in the form of salts of ammonia. The cheapest source for the supply of purchased ammonia at present known in commerce is Peruvian guano; in that form it can be obtained at from 6*d.* to 8*d.* per pound. The price of ammonia in dung depends on a great many circumstances. Mr. Lawes* found that a ton of rich box manure contained about 15 cwt. of water and 5 cwt. of solid matter. The ammonia amounted to 20 lbs. Whereas a ton of mere straw-litter wetted to the same degree contained about 5 lbs. of ammonia. The money value of a ton of dung may therefore be supposed to vary from 10*s.* to 2*s.* 6*d.* for the sake of its ammonia alone. The cost of producing the dung must of course depend in great measure on the market value of artificial food, and on the quality of the stock employed to consume it.

It is much to be desired that some careful experiments should be made in the West of England with a view to determine the amount of nitrogen required to produce a bushel of corn, and how far in our climate the application of manure can push the grain-producing power of the wheat-plant. At present we are quite in the dark on this subject.†

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* See further particulars in Royal Agricultural Society's Journal, vol. xii. pp. 28 and 31.

† The following facts may offer some suggestions to any one who is inclined to follow up the inquiry :—

Mr. Lawes, in 1847, started as a provisional hypothesis, to be further tested by experience, "that every bushel of corn requires 5 lbs. of ammonia," or, we may now say, an equivalent of nitrogen in some other form. We all remember how this hypothesis entered into Mr. Huxtable's calculations as to the possibility of growing wheat at 5*s.* a bushel.

In 1850 Mr. Lawes published the result of several years' experiments with farm-yard dung, showing that he had not been able to obtain more than 3-4ths of a bushel of corn for a ton of dung. Supposing this dung to have been nothing but wet straw, the ammonia required for a bushel would have exceeded 5 lbs. The dung in Mr. Lawes's yard doubtless contained at least 10 lbs., worth from 5*s.* to 6*s.*

Mr. Pusey found that, with nitrate of soda and salt, he could produce an additional quarter of corn for 24*s.* Mr.

With a view to avoid complication, I have hitherto spoken of ammonia as the chief source from which nitrogen is supplied to plants.

But Mr. Pusey's experiments, since Mr. Lawes' papers appeared, have shown that nitrate of soda cautiously applied with salt will supply the wheat crop with the nitrogen it requires. It is certain that in this case nitric acid, not soda, is the specific agent; and though there may be still a question as to the chemical state in which the plant receives its food, whether as ammonia, or as nitric acid, or both, there can be little doubt, after the perusal of Mr. Pusey's admirable paper (Royal Agricultural Society's Journal, vol. xiv.), that nitrogen is the staple food of corn crops.

In order to complete the subject of nitrogen, an account should be given of Professor Way's discovery of the absorbent power of clay, enabling it, when made porous by draining, to collect ammonia from the air. The practice of Mr. Smith, of Lois Weedon, throws very important light on the power of the soil when stirred annually to collect its own nitrogen, and to grow wheat profitably without purchased manure. But to these and other subjects space will only permit a passing allusion.

This paper, already too long, may now be brought to a conclusion by a short statement of the principles elicited from the practice of farming as conducted in England, and elucidated by the experiments of which some account has been given.

The analysis of crops, when taken by itself, is not a safe guide in the selection of manures.—p. 33.

The habits of plants must be studied as they actually occur in the rotations of husbandry.—p. 41.

The examination of the four-course rotation shows that where the green crops are consumed on the farm the amount of minerals removed from the land and not returned to it is small.—p. 36.

An abundant restoration of minerals will not by itself secure the profitable growth of plants.—p. 44.

Mr. Hope, of Scotland, obtained an increase of 10 bushels of wheat from 3 cwt. of guano, at a cost of 30*s*. (about 5 lbs. of ammonia to the bushel of corn), and a still larger amount with 1 cwt. of nitrate of soda and 1 cwt. of salt, costing only 18*s*.

The question, how to obtain the true food for corn in the cheapest form, is well worth a little trouble, while men can afford to try experiments, and before the experiment tries itself of necessity again.

These facts certainly point to the conclusion that dung is not the cheapest food for corn; but it cannot be too often repeated,—the power of manure in this climate has yet to be tested; and if practical men will unite for the purpose, our Society could hardly promote a more useful inquiry.

The mineral chiefly required to be imported is phosphorus—potash sometimes (lime and salt have special functions in certain cases).—pp. 35-46.

Carbon is largely consumed—that is, not only turned into meat, but burnt away—in stock-feeding; and, as there is no other available source, it must ultimately come from the air. If the plant is healthy it easily accumulates carbon.—p. 37.

Nitrogen is dissipated by corn-crops and grass; it is collected by clover, beans, and other leguminous plants; it is retained by root crops consumed on the farm; it is also collected by clay soils, when porous; it is imported as ammonia in guano, as nitric acid in nitrates, in various combinations in feeding-stuffs.

Carbonaceous matters, such as oil, starch, sugar, form fat in animals; but so much of them as passes through the animal into the dung is in time changed into carbonic acid, which has no appreciable money value, being abundantly supplied from the air.—See note to pp. 19-21.

Nitrogenous matters form flesh, and are only taken into the animal system in small quantities; but so much of them as passes through is found again in the dung as ammonia, which has a high money value, the supply being limited.

Therefore, the more meat is made on a farm, the more ammonia; and, under suitable conditions of soil and climate, the more corn.

The quicker the meat is made, the more profitably, as the less carbonaceous matter is wasted in proportion to the meat sold.

Extract from a Lecture on the Rev. S. Smith's System of growing Wheat at Lois Weedon, delivered by Dr. Daubeny, Sibthorpian Professor of Rural Economy in the University of Oxford.

It will doubtless be interesting to the scientific reader to peruse, in Dr. Daubeny's own perspicuous language, some remarks on Mr. Lawes' experiments, and on the origin of nitrogen.

"We know indeed from Mr. Lawes' own experiments that the turnip crop, in consequence of its wide-spreading leaves, can dispense with ammoniacal manure; and we are therefore perhaps entitled to conjecture, that a principle which is collected in such quantities by the leaves of a vegetable may exist in the air abundantly enough to enter into combination with a properly prepared soil in quantity sufficient to supply the wants of vegetation.

"If so, the original *dictum* of Baron Liebig, which has been so much controverted, may not be incorrect in principle; although the ill success of the mineral manure framed upon this assumption affords a useful lesson as to the risk we run of failure in applying to practice any general principle, in the present imperfect state of our knowledge of all the bearings of the question; since it undoubtedly appears from Mr. Lawes' experiments, that on ordinary soils, under a common system of cultivation, cereals are benefited by nitrogenous manures, on account of the large quantity of ammonia which is consumed in their growth over and above that which provides them with nitrogen —a fact which Professor Way, in his memoir on the 'Power of Soils to absorb Manure,' published in the 13th vol. of the Journal of the Royal Agricultural Society, attributes to the necessity of ammonia for rendering silica soluble, and thereby conveying it to the plant in the form in which it can constitute the epidermis of the straw.*

"The following may also be suggested as another possible source of the supply of nitrogen to plants.

"Schœnbein states that ozone, when brought into contact with nitrogen, an alkali, or an alkaline earth, being at the same time present, generates nitric acid, and he suggests this as a probable mode in which nitric acid is produced during natural as well as artificial electrical disturbances. Now, oxygen seems to be converted into ozone in every case of combustion, whether slow or rapid; and if by combustion, why not during that process of *eremacausis* which is taking place in all humus? Hence it is conceivable that exposure to air and light may enable a soil to supply plants with nitrogen, not only through the medium of the ammonia which it absorbs from the atmosphere, but likewise by means of the nitric acid which it causes to be generated owing to the ozone which its own *eremacausis* occasions. May not the difference of fertility in soils be in part connected with a difference in this supposed capacity?

"In a former lecture † I stated my grounds for objecting to the facts alleged by Professor Johnston in favour of the direct absorption of nitrogen, but the discovery of ozone and its properties seems to place the question in rather a new light, and to render the supposition a more tenable one.

"Accordingly it is not difficult to believe that, in so far as the organic constituents of the crop are concerned, no extraneous matters of an azotised nature, in the shape of guano, stable-dung, or nitrate of soda, may be required in this system of culture."

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* "Silica, according to Way, forms a soluble compound with ammonia, which, however, deposits its silica in an insoluble form as the ammonia flies off. Hence it is first taken up by the juices of the plant, and afterwards decomposed in the parts exposed to the air. Now this compound of silica with ammonia is not formed by the direct union of the two bodies, but only through the medium of a compound of silica, either with lime or with alumina, which exists in all argillaceous soils. These silicates, as it appears from Way's experiments, have the property of abstracting carbonate of ammonia from the air, and of retaining its base for the purposes of vegetation. Hence the fertility of the soil will depend upon the presence of these compounds, and, according to Way, the advantage of the Tullian practice of pulverising the soil consists in bringing these important compounds of silica which have the power of absorbing ammonia into contact with the atmosphere, and, consequently, producing with them the soluble silicates of the earths with ammonia, which is so important in husbandry."

† "I showed that in all the cases cited either the nitrogen or the oxygen was in a nascent state, but Schœnbein has justly observed that in the nascent state oxygen often exists as ozone."

PART THE THIRD.

In a former paper I endeavoured to explain in simple language some of the chemical principles involved in practical farming, as discovered in great measure by Liebig, and modified by the researches of Mr. Lawes and Dr. Gilbert. The soundness of the basis on which these researches rest has been called in question. Professor Liebig asserts that Mr. Lawes's experiments " prove what he intended to disprove," and " disproved what he intended to prove." These are strong assertions, and the book in which they are made is pronounced by the translator, Professor Gregory of Edinburgh, to be by far the best of the author's writings on the important subject to which it refers. Certainly the book has lost nothing in Professor Gregory's hands ; and the agreeable version of it, which he has given to the English public in a convenient form, has been extensively read, and attracted much attention through the medium of popular scientific literature. As might have been expected from former precedent, the philosophers who have not yet retired to their country houses and put their theories to the test of a little practical farming, have taken the side of the illustrious German. Mr. Lawes is disposed of in various ways : sometimes he is supposed not to have read Liebig ; at others to be unable to understand him ; and at others, to have wilfully misrepresented him.

The criticisms made upon his researches have been firmly and temperately met by Mr. Lawes ; and there can be little doubt that the result of so important a controversy will be to clear up the truth, to attract attention to it, to blow away a great deal of loose chaff which has hung about the main points involved. For this reason, if no other, the time would seem to be arrived for pressing on practical men, and especially on the rising generation of young farmers, the necessity of some attention to first principles as well as to unexplained practical results, supposed to bear directly upon marketable profit and loss. But there are other reasons : it is impossible not to notice that the traditionary rotations of agriculture are losing their authority over men's minds. The effect of the general use of artificial manures and of better implements, is to force on the attention of those who reflect and do not merely follow precedent, the inquiry whether the crops which pay best may not be grown in more rapid succession ; and whether fallow crops, if they cannot be made still more profitable or still less costly, may not be reduced in number. These questions may at no distant period assume a practical form, and it is much to be desired that no misunderstanding on the subject to which they refer should spring up between those interested in the ownership, management, and cultivation of landed estates.

But while thoughtful persons among practical farmers have been gradually arriving at the conviction that the soil of England is capable of adding yet further to its produce—already largely increased, and this without any fear of degeneration or ultimate loss of fertility—it is a remarkable fact that the alarm should have been sounded on our shores from the laboratory of Giessen, and echoed from the halls of science in Scotland; and this fear of the ultimate exhaustion of the soil for want of a due supply of mineral, has even found a voice among ourselves, as may be seen by referring to a paper on Tenant Security in the present Journal.

I must premise that in the following remarks I do not presume to give more than a plain statement of the impression upon my own mind made by the reasoning of Baron Liebig and his opponents. I cannot attempt to sift thoroughly a question requiring a knowledge of chemistry in detail, and those habits which result from laborious personal research in the advancement of science. There is some reason to hope that this task will be undertaken by one, perhaps of all persons in England the best qualified to hold the balance fairly between chemical principles and agricultural experience. But this much I wish to say to prevent misconception, that I have no dislike or suspicion of abstract truth—no blind adherence to existing practical traditions; so far from it that, as I have already stated on this very subject, I have the most absolute faith in natural laws and great principles if patiently and fairly worked out to their results; they must bring some fruit in the end; and so far am I from thinking that present practice can be our abiding standard, that I have been taught by one from whom it is a delight to learn, that only one thing is infallibly true in science, or at least in its applications—that where it is to day it will not be to-morrow; it is ever in a state of flux, moving slowly on, and learning, if it will only not close its ears, a lesson of humility, while it makes the surest advances towards clearer light and more accurate knowledge both of the vastness of nature and of the limits of its own strength.

THE QUESTION STATED.

What, then, is the practical question at stake in this controversy? Mr. Lawes maintains that in the majority of the soils of average quality in England mineral matters (with one exception) are rarely deficient, and are, practically speaking, inexhaustible, and that the addition of nitrogenous manures in the case of corn crops is the important point for farmers. But that in the case of the turnip crop there are circumstances acting in the opposite direction, producing this remarkable paradox in regard to one class of minerals, namely the phosphates, viz., that even when they exist to a considerable extent in the soil, a further addition of phosphate is *the* desideratum for the root-crop.

Liebig's doctrine, or at least the doctrine which has passed current under his name and authority is this :—That the produce of vegetables generally is in proportion to the minerals capable of assimilation ; and that inasmuch as ammonia is obtainable from the atmosphere (omitting the question of time) in sufficient and inexhaustible quantities, whereas the minerals are in steady process of removal from the soil, the restoration of the minerals is the important desideratum for the maintenance of fertility ; but that, as regards the turnip crop, Mr. Lawes's assertion of the necessity of phosphates in excess involves an impossibility.

I do not say that either of these statements exactly represents the scientific doctrine of either of the eminent experimentalists with whose name they are associated ; but that these two practical rules have been, and still are to some extent, advocated by those who range themselves respectively on the side of Lawes and Liebig.

I will put the matter still more shortly, in order to show its more special bearing on two crops :—

1st. As to wheat. The followers of Lawes maintain that nitrogen is the true food of wheat (whether as ammonia or nitric acid), and that phosphates, &c. do not increase the crop.

The followers of Liebig maintain that certain minerals, and especially phosphates for the seed, silicates for the straw, are the true manure of wheat.

2ndly. As to turnips. The followers of Lawes maintain that in the case of turnips, ammonia only increases the leaf, but that, a special addition of phosphate is necessary to increase the root, even although there may be a considerable supply of phosphate in the land already.

On this point Liebig shall speak in his own words :—" It is impossible to believe that the effect . . . . can have depended on the newly-added phosphoric acid, as Mr. Lawes concludes." And again, " It is out of the question, after the facts now related, to assume that the excess of the phosphoric acid was necessary or was the cause of the increase."

When a person of Professor Liebig's high scientific position makes such assertions, with a knowledge that his words will excite attention throughout Europe, he must be supposed to have some clear perception of his own meaning, and in the absence of special circumstances pointing to a contrary conclusion, the mere fact of such a statement having been made from such a quarter makes one hesitate and re-examine any opposite conclusions; for either we must suppose that he knows his own position to be unassailable because he sees further or deeper than other men, and perceives some ignorance or confusion of thought in his opponent; or else we are driven to the only other conclusion which remains to be drawn, that impatience of contradiction has somewhat impaired the coolness of his judgment and prevented his looking dispassionately at all the conditions of the problem.

Into the personal part of the controversy it is needless for me to enter; first, because Mr. Lawes has triumphantly vindicated himself; secondly, because the discussion of such personal claims is always tedious to the reader; but a slight retrospect of the points involved may not be without its present value.

WHAT WE OWE TO LIEBIG.

I have already pointed out in a former part of this paper how entirely ignorant mankind in general were of the rationale of the commonest facts of agriculture known by mere experience to every tiller of the soil, until the time of our illustrious countryman Davy, to whom as well as to De Saussure, Liebig has done full justice. But the striking effect produced by the appearance of Liebig's 'Agricultural Chemistry,' in 1840, is well described by Mr. Thompson, in the last number of the Royal Agricultural Journal (No. 36).

"It will be in the recollection of all who have watched the rise and progress of this important controversy, that, in the year 1840, Baron Liebig first published in this country his great work on Agricultural Chemistry. At that time a very general impression prevailed that British agriculture was capable of great development, but that there were no established principles to guide its advance, nor even any sure ground on which to tread if any deviation were made either to the right or to the left of the beaten track marked out by our forefathers.

"The appearance of Baron Liebig's book was, therefore, naturally and deservedly hailed with great delight. All admired the masterly way in which he traced the elements of vegetable life to their original sources, pointed out their chemical composition, and followed them through the various stages of the plant's development and maturity, until the process of decay had again reduced them to the elementary form. His main position, too, that in order permanently to maintain the fertility of cultivated land, it was necessary to restore to it all the substances contained in the various crops exported from the farm, was as new to agriculturists as it was convincing, and its application to practical agriculture seemed as simple and easy as it has since been found to be complicated and difficult.

"For the time, however, the whole secrets of the science of agriculture seemed to be laid open by the production of this master-key; nor could it well be otherwise. The accuracy of the chemical investigations which formed the basis of this work has never been questioned, and the reasoning with which the various results were united into one consistent and comprehensive scheme, seemed so sound and satisfactory, that the delighted reader was led on by easy steps until he reached an elevation from which it was difficult to avoid believing that the prospect before him included the whole *past*, *present*, and *future* of agriculture."

I think the most important points brought to light and made popularly intelligible by Liebig are the following:—

1. Liebig proved in the first edition of his work, published in 1840, the fallacy of the theoretical notions then current about *humus*. He clearly showed that the vegetable juices, supposed to be the great causes of richness in garden mould, could not be imbibed by other plants till they had been decomposed; in other words, that the carbon of plants must first be turned into carbonic acid, in order to be assimilated by plants, whether they derive it from the soil through the roots, or from the atmosphere through the pores of their leaves.

2. In like manner Liebig proved that the nitrogen of plants is obtainable in the form of ammonia, provided that ammonia is to be met with in sufficient quantities; and that ammonia, in appreciable amount, is always to be found in the atmosphere, and descends with the rain into the soil.

3. We owe to Baron Liebig, if not the first clear proof, at least the copious illustration and popular diffusion of the doctrine, that every kind of plant has certain specific *mineral* elements, every one of which, in its due proportion, must be assimilated by the plant or it will not thrive, and, as a consequence—which is, in fact, the same truth stated negatively—that a deficiency of any one of the mineral elements proper to each plant would be fatal to its healthy growth; or if the deficiency should be absolute, then fatal to its life.

It is generally assumed, as a necessary consequence involved in this last proposition, that a supply of these minerals in manure will promote the life, health, and development of a plant. It is very probable that this may be so; and if physiology were a branch of abstract or pure mathematics, doubtless the hypothesis or definition of plants, mineral, &c., would so circumscribe the ideas involved in the terms of the proposition, that the one would involve the other, and *vice versâ;* but any one who has thought a moment on the relation between mathematical and experimental proof, will see that such demonstrations can only be made in physics by granting the use of terms which assume the whole point to be proved, and therefore prove nothing as a matter of fact which has not been made good by experiment. In mathematics, the truth that all equilateral triangles are equiangular involves the converse—that all equiangular triangles are equilateral; but to show by induction that plants require certain food, does not prove that an increase of the food will produce an increase of the plant, unless we are sure that we understand all that the life of the plant involves.

Now that our young farmers are encouraged to pass, and some I rejoice to know have creditably passed, an examination in practical mathematics, they will, I hope, appreciate the wide difference between mathematical and experimental proof. There is, however, one form in which the Baron's friends may put their argument, which I will undertake to say shall be fully appreciated by those who are most alarmed at the sound of mathematics; and that is by producing a mineral manure which shall place an additional sack of wheat per acre in each corner of a triangle.

THE PROFESSOR'S FARMING TOUR IN ENGLAND, AND ITS RESULTS.

Had Liebig been content with enunciating, if he did not discover, the beautiful laws above referred to, and laying them before British farmers in the agreeable form in which he first put them forth, his writings would have continued to shed a brilliant and constantly increasing light on the mysteries of practical farming. Experience in the field becoming daily more intelligent, would have been also more intelligible ; there would have been no seeming collision between practice and science; and our induction of well-observed facts would have widened by the aid of a willing and delighted body of learners. Meanwhile the researches in the laboratory, guided by the aid of physiology, and following into its more hidden recesses the workings of life, might, ere this, have explained much that seems at present all but inexplicable.

But, unfortunately, Liebig took two steps, apparently in consequence of "a journey through the agricultural districts of England and Scotland," during which "he endeavoured to make himself acquainted with the condition of practical farming, and what it requires." He published a new edition of his work, in which he left out some passages, which seemed to the unlearned very sensible, and added some very questionable advice to practical farmers. And secondly, he allowed his name to be used in connexion with a patent manure which turned out a complete failure. Now, practical farmers in England (and in Germany too, as some recent hints lead us to suspect) have some ways of their own, and one of them is, that when a professor takes a tour round the country they like to have a joke with him, and to give him a hearty welcome at their table, but they do not often listen to his advice about farming: and another of their ways is, that they like to buy a manure because neighbour so-and-so has tried it and found it answer; and they very seldom buy what the professor tells them will answer, because, quoth he, being made according to the newest theory, it ought to answer.

Now, it may be very true that the habits of mind referred to are more favourable to the promotion of good humour and to the saving of the pockets of manure-buyers than to the advancement of abstract science on the one hand, or to the profitable investment of capital in patent manure speculations on the other; but perhaps in the long run true science and the manure business will gain by the time spent in convincing Farmer John of his true interest by the tardy process of experience. It was a saying of a distinguished Frenchman, "Nothing is so successful as success."

Effect of the Professor's Teaching on the Manure Market.

The result of the propagation of Professor Liebig's views, accompanied by his practical advice, was, that he soon was followed by a host of imitators and manure makers, who, learning from his work that plants were to be classified, as potash plants, silica plants, &c., bestowed much attention on the composition of the ashes of plants, in the hope that when that was duly ascertained, farming would be reduced to a simple equation: "given the elements of the soil and the composition of the plant, required the manure." Few of us who have attended to these subjects have not been influenced by these ideas, and, after telling our gardeners and bailiffs that such-and-such minerals must be good for such-and-such plants, have been doomed to disappointment on hearing the oft-recurring answer, "I put in the manure, sir, as you told me, but I have never been able to see a bit of difference in consequence;" followed by the customary reflection, "I think, sir, good dung is the best after all;" to which the rejoinder, "Yes, if there were enough, and if it cost less for cartage," is hardly deemed a sufficient proof that we have found anything either better or cheaper, so far.

I know not what the experience or reading of others may have taught them, but I cannot recall one clear case in which a manure founded simply on the ashes as an evidence of the mineral constitution and supposed mineral demands of the plant has produced any immediate effect whatever.

Phosphate will naturally suggest itself to the reader, but the exception proves the rule, for this is the very mineral which will (most provokingly to the professorial mind) seem to produce an effect which it has no right to produce, and of which, as Liebig assures us, it cannot be the cause, because the plant only requires so small a quantity of phosphate. Now, turnips contain a great deal of potash, and wheat contains a great deal of phosphate and silica; what we want to find is clear proof of potash increasing our swedes, and phosphate and silica increasing our wheat-crops.

As an illustration of the practical mischief done by the propagation of erroneous or at least crude scientific recommendations on the subject of manures, I may refer to the fact that a manufacturer of a manure grossly adulterated with sand, actually had the impudence to insert an analysis in his advertisements, in which the sand figured as silicious constituents, relying of course on the farmers having duly studied Liebig's doctrine of the value of silica to the wheat plant.

Mr. Pusey, with his accustomed acuteness and good sense, early saw how little would come of the elaborate analysis of the ashes of plants; and how scanty is the whole sum of the knowledge we really possess of the means by which plants get their food. He quickly perceived, also, the true value of Mr. Lawes's experiments, which went straight to the question—How are we practically to secure our turnips and to increase our wheat-crops?

I need not go again over old ground and relate the successive steps by which valuable practical truths were established at Rothamsted. It is sufficient to repeat, that Mr. Lawes found that on his own soil he could by no combination of manure raise his wheat-crop a single bushel beyond the natural produce yielded by the unmanured soil year after year, whereas by the addition of ammonia he at once gained from 10 to 15 bushels per acre, and this also year after year for above 10 years.

After all that Baron Liebig said in his 3rd and 4th editions in the way of practical advice to English farmers, and after the propagation of views in consonance with this advice, it is idle for his followers to vindicate the soundness of his views by ransacking his works for sentences in which he asserts abstractedly the value of ammonia. I have read through the greater part of his work more than once, in order to ascertain exactly what he did say, and it is quite true that many passages may be found in which the importance of ammonia is asserted, though it is generally left very uncertain whether the ammonia meant is the natural supply afforded by the atmosphere, or whether it is intended to include ammonia added in the manure. In the fourth edition especially is added a very able chapter, called a Retrospect of Preceding Theories, containing elaborate criticisms on some experiments of Boussingault and others, which criticisms, if strictly examined, go no further than to prove that ammoniacal manure alone, without an additional supply of minerals, will neither increase produce nor sustain fertility, *on land in which the required minerals were originally absent, or in which they have been exhausted:* but the obvious drift and effect of the chapter is to lead to the idea that the addition of ammonia is a matter of indifference. The chapter contains, it is true, many qualifying clauses, especially those which admit the stimulating effects of ammonia, or, as Liebig expresses it, the gain of time attributable to carbonic acid and ammonia; but of what avail is it now to quote such clauses when the chapter winds up with the following practical advice:

"By means of ammonia, in the form of animal excrements, we increase the quantity of the constituents of blood in our cultivated plants, an action which the carbonate or sulphate of ammonia *alone* never exerts.

"In order to obviate any misunderstanding, we must again draw attention to the fact that this explanation is not in any way contradicted by the effects produced on the application of artificial ammonia, or of its salts. Ammonia was, and is still considered, as the source of all the nitrogen of plants. Its supply is never injurious; on the contrary, it is always useful, and, for certain purposes, indispensable. But at the same time it is of great importance for agriculture, to know with certainty that *the supply of ammonia is unnecessary for most of our cultivated plants, and that it may be even superfluous if only the soil contain a sufficient supply of the mineral food of plants, when the ammonia required for their development will be furnished by the atmosphere.* It is also of importance to know, that the *rule usually adopted in France and in Germany of estimating the value of a manure according to the amount of its nitrogen is quite fallacious*, and that *its value does not stand in proportion to its nitrogen.*

"By an exact estimation of the quantity of ashes in cultivated plants growing in various kinds of soils, and by their analysis, we will learn those constituents of the plants which are variable and those which remain constant. Thus, also, we will attain a knowledge of the quantities of all the constituents removed from the soil by different crops.

"The *farmer will thus be enabled*, like a systematic manufacturer, to *have a book attached to each field*, in which he will note the amount of the various ingredients removed from the land in the form of crops, and therefore how much he must restore to bring it to its original state of fertility. He will also be able to express in pounds weight how much of one or another ingredient of soils he must add to his own land in order to increase its fertility for certain kinds of plants.

These investigations are a necessity of the times in which we live; but in a few years, by the united diligence of chemists of all countries, we may expect to see the realization of these views; and by the aid of intelligent farmers, we may confidently expect to see established, on an immovable foundation, a rational system of farming for all countries and for all soils.*—*Liebig's Chemistry*, Part I. chap. xiii. pp. 212-214. *3rd edition.*

The fact is plain; these practical conclusions, which are the best interpreters of a man's real opinions, are on record, *litera scripta manet*, and from them there is no escape except on one of two conditions—either by making the practical advice succeed in increasing and cheapening human food, or by admitting that he committed an error of judgment when he allowed his name to be connected with a patent manure founded on the principle of

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* I have given the above extract at length because detached passages of it have been quoted on opposite sides, and it is important to look at its general drift.

supplying to plants only, or chiefly, such mineral elements as are found in their ashes.

EXHAUSTION OF SOILS.

Nor is the cause of true philosophy strengthened by falling back on a merely negative view, and changing the form of the doctrine into what may be termed a prophetical version, and foretelling the progressive and ultimately complete exhaustion of the soils in certain countries as the result of the continued growth of some of the most important plants.

Of course if it can be shown that in the surface-soil and in the subsoil taken together there is less of any particular mineral than suffices to bring within reach of the plant its appropriate mineral food in due proportions, then it is implied truly and practically in the original fundamental law that that particular mineral must be artificially supplied in an available state, or the plant will not thrive in the soil referred to. This has never been denied—certainly not denied by Lawes—and the whole of the seeming brilliancy and success of Liebig's reply is due to the rhetorical artifice of making it appear that Lawes has committed the absurdity of maintaining the doctrine that, because his corn crops were in fact increased by nitrogen and were not increased by minerals, they did not require to find their *quantum sufficit* of minerals in the soil; and then of showing unconsciously, by his own elaborate experiments, that such a doctrine is destitute of foundation.

But supposing it to be true, as prophesied by Liebig, that our soils are in a progressive state of exhaustion, what avails it to the practice of agriculture to show that there is a remote contingency that a hundred years hence the value of the staple of the soil will be diminished. This offers no practical inducement to the tenant farmer of to-day to replace the abstracted mineral for the benefit of his landlord's great-grandson, *unless* you can show him that by so doing he will increase his own crops beyond what he can by good management get out of the land as it is during the probable term of his own occupation, or that for want of the proposed supply of minerals his land will drop into worse condition during the same limited period.

Moreover, it argues but little faith in the undeveloped resources of physical science, or of human enterprise and ingenuity, to doubt that long before soils now called fertile can become exhausted, many fresh means will be found of fitting the supply to the demand of the soil, or rather to the demand of those who live upon its produce.

Science catechized by Practice.

Well, then, corn and green crops being the great desiderata for the food of man and beast, the demand addressed by Practice to Science at the present day stands thus, with reference not to vegetation in the abstract, but with reference to the above-named cultivated crops:—

1. Is there a *present* risk of exhausting my land of certain mineral elements which you have shown to be essential to my crops?

2. If there be such a risk, can you tell me, by analysing my particular soil, which the elements are of which the supply is likely to run short in my time or my son's?

3. Can you further tell me where I can purchase a supply suited to my case, and in such a state that I can depend on its being beneficial to my crops by increasing them, or to my pocket by reducing the cost of such as I am now able to produce by the somewhat expensive method of high-farming?

4. On the other hand, if there be no such practical risk, can you tell me by what means I can get more out of my land—that is, can you teach me to bring its abundant resources more quickly into play by the addition of any solvent or stimulant not found in the soil in its natural state?

To the first three demands no other answer has been given by the followers of Liebig except a vast accumulation of ash analyses, and a patent manure which has long been forgotten because it did no good.

To the fourth question the answer was—that an artificial supply of ammonia was "unnecessary" and "superfluous," and "limited to a gain of time,"—expressions which, however they may now be defended, can only be so by admitting that they were ambiguous and thoroughly misleading to practical men.

The question was in this position when it was taken up by Mr. Lawes; and very different was the reply given from the great open-air laboratory of Rothamsted. Putting under strict chemical management a portion of his farm so large as to justify the confidence of practical men in results worked out not with washing-bottles and filters, but with an average soil and the showers of the heavens, Mr. Lawes replied in substance as follows:—

1. To your first question I say, that as regards wheat, I see no signs of exhaustion in my soil, for I can grow 16 bushels of wheat year after year on the same land without manure. As regards roots, I do see a certainty of exhaustion, for my turnip crop became fine by degrees and beautifully less, until it was reduced to the likeness of a bed of radishes in the second or third year.

2. To your second question I answer: I find that it is especially the stock of available phosphates which is quickly run out by my root-crops.

3. I find that Liebig's recipe for dissolving bones, together with other subsequent improvements in the methods of supplying phosphate of lime in a finely divided state, enable me both to increase the weight of my turnip-crop and to diminish the cost of its production.

4. In the case of corn-crops, where the soil does not show signs of exhaustion, and therefore implies an abundant supply of mineral matter, I find that the addition of nitrogen, whether in the form of ammonia or of nitric acid, does enable me to take more corn to market year after year, the profit or loss of the operation depending on the price at which I can buy nitrogen and sell wheat.

It is not easy to imagine any answer more complete or satisfactory for practical purposes as far as our knowledge goes at present. All that is needed is to inquire whether the answers are dependent on peculiarities in Mr. Lawes's soil not to be found commonly elsewhere; and this implication, founded on no examination into the fact that I am aware of, has been the constant weapon of those whose wishes being father to their thoughts, were pre-disposed to decry Mr. Lawes out of deference to the authority of the great philosopher on whom they think he has made a needless attack in his paper on the Mineral Theory. Over and over again have I been told by those of my chemical friends who support Liebig, "the experiments are worth nothing, because Lawes did not analyse his soil before he began them. How are we to know what might not have been in the soil? What would you say to a chemist who conducted a careful analysis without taking care that his bottles were washed and his *aqua distillata* pure?" "Well, but what will you say if all the dusty bottles in England yield the same conclusions, with the exception of a few particular cases, in which we knew beforehand, from what had been in the bottles before, that our results would be modified, and they were modified accordingly? The Rothamsted dust won't much affect the question then, will it?" The fact is, that so strongly have Mr. Lawes's conclusions been supported by experience in all parts of England, that as Mr. Thompson observes, the chemical creed of the English farmer begins and ends with two axioms—"that *nitrogen* is the principal desideratum in a manure for *corn*, and *phosphorus* in one for *turnips*." And as a natural consequence, from the time that Mr. Lawes's papers appeared, the sale of phosphate of lime for turnips has steadily increased, and its use has become general throughout England, except on certain soils, such as those at Farnham, on the greensand, and a few others, in which there may be some reason to suspect a liberal supply of phosphate ready for use.*

With regard to nitrogen, I believe wherever it has been tried with due care its effect on the wheat-crop as maintained by Lawes has been fully borne out by experience, and this not only on clay soils, but also on light soils, for examples of which I may refer to the experiments of Mr. Keary at Holkham, the Duke of Bedford at Woburn, and of the late Mr. Pusey, as reported in the Bath and West of England Agricultural Journal, vol. iv. p. 96.

And in all this there has been no disrespect shown or intended to Liebig; his original principles have been taken for granted, as the guiding light throughout the conduct of the inquiry, which has only had for its object to give them a correct application to the facts and requirements of the food-supply of England.

The difference between the courses pursued by the two champions is the only matter to be regretted by the Baron's friends. Mr. Lawes commenced by working out Liebig's principles, and in doing so found it necessary to supply a modification as a correction, viz., that ammonia or nitrogen must be artificially supplied to increase the wheat crop. The utmost that can be said against Lawes's doctrine is, that some of his followers by talking about nitrogen as the true *food of wheat*, gave colour to the imputation that in their opinion wheat needed not its proper mineral food also. But this was plainly assumed in all Mr. Lawes's arguments as sufficient in every case in which the nitrogen was efficacious.

Liebig, on the other hand, irritated apparently by Lawes's success, and by the effect which Lawes's paper has produced in Germany, seems determined to crush his opponent—*si possit recte, si non quocunque modo;* and the *modus operandi* appears to have been, silently and without acknowledgment to adopt Lawes's correction as to the value of ammoniacal salts, to claim it as a part of the original Giessen theory, which it may perhaps be admitted to have been, until it was, for practical purposes, abandoned in the third edition. The theory of Agricultural Chemistry, thus duly adjusted with practice, is then presented in its stately proportions, and the Rothamsted experiments are used for the purpose of maintaining a sound theory, as if it had not been denied; when the experiments differ from the theory as now held, the policy has been to turn them into ridicule or to endeavour to treat them as inapplicable and valueless.

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* It is much to be wished that the owners and occupiers of such soils would carefully examine into the facts and report upon them. When I was engaged on my Report on Somersetshire Farming, I met with the opinion that phosphate had no effect on some of the rich soils in the south-east of the county. The investigation into this subject would be a real contribution to agricultural science.

Truths elicited by the Controversy.

I began by stating that out of this controversy truth, both practical and scientific, would come out more clearly. It may be well now to collect, without further reference to the personal questions involved, the truths firmly established, by admissions on both sides, and then to point to some open questions, which seem to remain still undecided.

For this purpose we cannot do better than refer to the summary contained in Professor Liebig's last work, in the form of fifty consecutive propositions, of which his translator, Professor Gregory, says that they are " beyond all doubt true, so far as our present knowledge extends "—that they " embody the principles of Agricultural Chemistry, or rather of the Science of Agriculture," which Professor Gregory has " deduced from the author's writings," " has long taught in his own lectures," and that he regards them as so certain, that " all improvement in agriculture will be found to be referable to these principles, or laws ;" in short, as Baron Liebig has said, " therein lies the whole future of agriculture."

After several attempts to state the substance of these fifty propositions, in the order in which they are arranged by the author, so as to give a fair representation of his meaning, and at the same time put the matter in a form suitable to the agricultural reader, I have abandoned the attempt to follow step by step the train of the author's reasoning, and must recast them under certain heads, giving merely the practical results. They are so very skilfully concatenated, and interwoven, as it seems to me, with a view to the effect intended to be produced on the reader, that they would inevitably lead us back into the personal controversy. The impression which I believe they are intended to leave on the reader is, that what has been called the Mineral Theory is substantially true ; that the practical value of the addition of ammoniacal salts on manure was always a part of that theory ; and that the specific value attached to phosphate of lime by Mr. Lawes is an unimportant trifle, unphilosophically stated by Mr. Lawes, and in no way affecting the practical consequences of that theory ; in short, that Mr. Lawes has given himself a great deal of trouble to no good purpose.

The book, containing the fifty propositions referred to, opens with one of those masterly sketches, which no one is better able than Liebig to draw with a few touches. It sets before us the relation between the natural laws, discovered by science, and the practical processes involved in any art or manufacture, and shows in bold relief the contrast between those creatures of the imagination, which used to be called theory, but which, in fact, were guesses or fanciful notions, and a true theory, which traces the connexion between any observed fact and the known natural laws or causes producing that fact.

A truly practical man in the best sense of the word, as Liebig observes, ought thoroughly to comprehend the natural laws involved in his own business, not learnt by rule of thumb, but seen by the light of clear reason and extended observation. Such a man's wits, sharpened by the true theory of which he is fully master, will keep him constantly on the look out for the means of turning the laws of nature to the best account. Such are the practical men who cheapen and render daily more perfect the processes in our manufactures, and why should we not have such practical men in agriculture also? There is much need of such if we may go on hoping for a true science of agriculture, of which we are at times almost tempted to despair, seeing on the one hand the dogmatism of science, and on the other the indolence—not therefore the less positive and dogmatic—of practice.

Liebig's Summary of Agricultural Principles.

Liebig's fifty propositions may be arranged under the following heads:—1. The nature of plants; 2. The nature of the soil; 3. The obstacles to the growth of plants; 4. The effect of the growth of plants on the soil; 5. The effects of cultivation; and 6. The effect of manure on plants.

Plants.

"Plants in general receive their carbon and nitrogen from the air; the first in the form of carbonic acid, the second in that of ammonia" (prop. 1). "Nitric acid" also "a source of nitrogen" (prop. 10). "Carbonic acid and ammonia are the *atmospheric food of vegetables*" (prop. 20).

"Plants also invariably contain a certain number of mineral substances" (prop. 2). These are known by the ashes, and are "included in the terms *mineral food of plants*" (prop. 20). "Different plants require . . . . either the same mineral substances, but in unequal quantities or in unequal times," or require some special minerals not common to all plants.

But all the "substances necessary to the growth of a plant," whether atmospheric food or mineral food, "are of equal value"—that is, if one of the whole number be absent, the plant will not thrive (prop. 21).

This is intended to meet the idea of ammonia being the food of wheat, phosphorus the food of roots.

The growth of a plant, other conditions being equal, is in proportion to the extent of the surface of its absorbing organs, whether leaves, or roots (prop. 36).

The different lengths of roots of plants enables them to feed on different portions of soil at different depths (prop. 38). Also the season of the year and rapidity of the development of a plant, must be considered in supplying its food (prop. 39).

This bears on top-dressing and on phosphate.

Soils.

Soils capable of growing any plant must contain the mineral substances proper to that plant (prop. 22).

The mineral matter in the soil may be dormant, as in rock undecomposed, or it may be in a fine state of subdivision, available for immediate use by plants. Hence arises definition of fertility (props. 22-25).

Fertility includes two ideas: first, the presence of food for plants in sufficient *quantity*, whether immediately available or not; secondly, the *quality* of such food, *i. e.* its solubility, and generally its being in a state fit for immediate use of plants.

Much of Liebig's argument turns on this double use of the word fertility.

The different mineral elements of a soil vary in solubility and in the rapidity with which they are acted upon by the weather; hence the theory of Fallows (props. 23-31).

The effect of Cropping on Land.

If crops are taken off the land they remove some mineral substances. Liebig asserts or implies that this removal is "a probable cause of diminished fertility." "A fertile soil contains more of these constituents than a poor one does" (prop. 4 taken together with 6).

If fertility means a certain quantity of minerals, this is necessarily true; but if the quantity assumed to be limited in amount is practically unlimited, and if what is left to be accounted for is in an available form, there is no loss of fertility in the common acceptation of this term.

The effect of crops on land varies, because all do not remove the same substances. From this principle, taken together with the theory of Fallows, as above, results—

The theory of Rotations (props. 32-35), namely, that one plant will grow in land which is, for the time being, barren for another plant (as we talk of land being clover-sick), while the weather and other causes are getting ready a fresh supply of minerals in a state of solubility.

On this we might ask why does no one talk now of land being turnip-sick?—and the answer will be, for nearly all English soils, because we have found out a cure for the sickness, superphosphate of lime.

Obstacles to Growth.—(Prop. 25.)

The obstacles to the growth of plants are those mechanical or physical conditions which impede the penetration of the roots, as when the subsoil is a hard rock; or which impede the free circulation of air and water, and, as a consequence, retard the solubility of the minerals, as in the case of compact and undrained clays.

Poisonous substances might also be considered as obstacles to growth.

Effects of Cultivation.

The first effect of cultivation is the removal of obstacles by draining, ploughing, &c., with a view—

1. To expedite the weathering, or rendering of minerals soluble (prop. 25).
2. To increase the power of absorbing carbonic acid and ammonia from the atmosphere, from the rain, or from manure (prop. 26).

Another form of cultivation is compression with a view to ensure a firm seed-bed, or to retain manure.

A third is the roughening of the surface with a view to increase radiation of heat, and so to keep the soil cool and moist (horse-hoeing, &c.).

Fallows and tillage, followed by the removal of crops, cannot alone enrich a soil; on the contrary, they tend to its impoverishment (prop. 30).

In other words, the chief effect of tillage is to accelerate the conversion of fixed into moveable capital (prop. 24).

Effect of Manures.—(Props. 5, 9, 11, 14, 15.)

The effect of animal excreta, as shown by experience, is to restore practical fertility. Their mode of action is threefold: 1st, they restore the mineral constituents removed in the crops; 2ndly, they add to the atmospheric supplies of carbonic acid and ammonia; 3rdly, they supply, in the latter form, solvents of the minerals.

The functions of animal excreta (which are the normal type of food of vegetables, as milk is that of the food of animals) may also be stated thus;

1st, they add to the general resources of the land, whether by adding to the fixed or the moveable staple, whether they increase the mineral or the atmospheric stock; 2ndly, they supply (when skilfully adapted) the wants of particular plants, whether acting as solvents (ammonia), or presenting to them some one element not to be found *within reach of the plant* in sufficient quantities (see below, page 79, as to phosphates).

Liebig's doctrine as to phosphate is: "Where phosphate of lime, given alone, is found efficacious, it is" only "a sign that the substance was absent, or present in too small proportion, whereas there was no want of others" (prop. 41).

Liebig's Practical Conclusion.

The maximum of produce depends on the "quantity and quality of the mineral constituents in the soil;" "the absence of obstacles to their efficacy (physical qualities of the soil);" and "the amount of the atmospheric constituents supplied by the air and the soil (including manure)."

This practical conclusion, *which includes all that has been contended for by Lawes*, is drawn out by Liebig into a number of carefully wrought up antitheses; but they are all, in fact, identical propositions, or nearly so, to this effect:—When a soil has enough of any constituent, mineral or atmospheric, it has enough, and to add more is useless; when any element is deficient, the defect must be supplied. The question is, What is "enough"? what is meant by "deficient"? Is the plant-feeder to ascertain the answer by consulting the tastes of the plant while it is alive, or by dissecting it after its death? In a word, by field experiments, or by ash analyses?

I think the substantial truth, cleared from ambiguous language, is as follows:—

1. When minerals are absent, or are running short, they must be supplied, if the permanent standard of *quantity* is to be kept up. *This is granted.*

But Liebig would seem to suggest as included in this, what is quite another question, that the supply of these minerals will keep up the standard of *quality*, *i. e.*, will increase the crop at once, and that the crop will be "*in proportion to the supply of minerals in the manure*" (prop. 44). *This is denied*,—at least until we have some practical proof of its truth.

2. An addition of atmospheric constituents will increase the produce, if the minerals are present. *This Liebig* NOW admits.

The addition of atmospheric constituents is *necessary* to increase the crop beyond a low average. This Lawes has proved in the case of wheat, and Liebig evades.

3. Atmospheric constituents added in the manure tend to the exhaustion of the land of its minerals.

In cases in which the stock of minerals is limited, this is admitted on all hands ; but on soils in which it is practically unlimited, the principle has no agricultural importance.

Principles of Physiology assumed in Liebig's Theory.

In drawing out the admitted truth contained in Liebig's summary I have found it impossible to confine myself to a bare repetition of his words. But if the reader will take the trouble to read through the propositions for himself, I do not think he will accuse me of intentional misrepresentation. I have only endeavoured to reduce generals to particulars, and to disentangle ambiguities. There is something unsatisfactory in such an attempt to cover the whole ground of a science, yet in an early stage, as if to put in a claim to all future discoveries, by drawing up in array an imposing front of propositions, couched in very general, if not in actually ambiguous terms ; one proposition seeming to flow out of another as if by *à priori* reasoning from hypothetical definitions and assumed postulates, as in geometry, leaving their actual correspondence with the observed facts of nature in a very indeterminate state. There is also, what I have noticed in all Baron Liebig's writings with which I am acquainted, a disposition almost to ignore, or, at least, to admit most grudgingly, the existence of vital action,* as if all the phenomena of life had been already resolved into a few mechanical and chemical properties of the particles of matter.

Now, though it may be granted that the terms "vital action" and "life" are only signs symbolical of human ignorance, and therefore such as ought to be used cautiously in order to avoid the just charge of vagueness, lest we offer creatures of imagination as causes, when in fact they explain nothing ; still it is the fact that we do know nothing of life but its effects, and that effects do exist of which the causes are at present unknown. And therefore, although by elaborately setting out these effects in general terms which add nothing to our previous knowledge, and by tracing logical deductions from natural laws, which he cannot at present connect with the facts, our author may seem to give chemical explanations of natural occurrences, nothing more is in fact gained than by giving names to the creatures of our imagination in such words as "vital force," "stimulants," &c.

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* I am aware of the striking passage on chemical and vital force in the 'Familiar Letters,' p. 16.

It will be observed, then, that throughout this summary Liebig takes for granted that the behaviour as it is technically termed in the laboratory, that is, the sum of the observed individual properties of each chemical element, as it is isolated by the chemist, is all that we have to take account of in the contact between the mineral and vegetable world; that in the words "soil," "air," "water," "manure," which are collective terms, there is nothing more than a sum of separate conditions, which the chemist can analyse, distinguish, and tabulate in a catalogue, or, to quote his own words (p. 16):—

> "If it be an established fact that soil and water and manure exert an influence on the growth of plants, it is no less certain that they can only do this by means of their constituent parts, and the duty of the chemist is to make known to the man who is occupied in the culture of plants these constituents, their properties, and their chemical action or behaviour."

Doubtless, when the human mind has attained to perfect knowledge, this will be true: but the question may be fairly asked, have we yet arrived at this point, so that the rough and mixed facts of the field can be reduced by an exhaustive process to their elements, with a certainty that nothing has been overlooked?

Again, the Baron lays down the principle that "the growth of a plant, its increase in mass, and its complete development in a given time (all other conditions being equal) are in proportion to the surface of the organs destined to absorb the food of the plant" (prop. 36). Perhaps this is true, in the guarded terms in which it is here stated; the tendency of botanical knowledge has doubtless been to show that plants are merely passive; that their circulation, if there be any, is of the simplest possible kind; that they are not subject to stimulus as if they had nerves; that the upward flow of the sap is to be accounted for by capillary attraction. But still we may ask, what is the meaning of the endless varieties of sorts of the same genus, quite as remarkable as the varieties of races, breeds, and families in the animal creation? If plants are such mere passive machines, what is the explanation of the fact that the turnip, with all its varieties, and the countless forms of cabbage, brocoli, savoys, Brussels' sprouts, are but various types of one original plant, distinctly traceable to their common origin? Or again, what is the circulation of the vallisneria seen under the microscope? It seems as if we should be cautious of assuming that physiology may not throw some fresh light on the vital principles of those little cells, which hand on their own peculiar life from generation to generation of plants, each having life in itself, each yielding seed, or yielding "fruit whose seed is in itself, after its kind."

However, I must not be tempted too far by this train of reflection. I only wish to point out, that in the seemingly consistent and almost demonstrative string of propositions under consideration there may be less daylight than at first sight appears; and that there is nothing in *à priori* reasoning on such subjects to render undesirable the patient investigation into the facts of common agriculture set on foot (if we except Boussingault) for the first time by Mr. Lawes; certainly nothing to justify the slighting and contemptuous tone taken up by Baron Liebig.

Present State of the Question.

The practical result of these propositions, as far as we can accept them for a record of what has really been discovered by *bonâ fide* induction from observed facts, is this:—

It is admitted that there can be no fertility without a full supply of the required minerals in the soil, of which none can be absent without loss to the crop.

It is admitted that (whether required as independent constituents, or as solvents of minerals) carbonic acid and ammonia are obtainable from the atmosphere, but that a further application of these in the form of manure will accelerate or increase produce (unless by overgrossness the plant is rendered unfit for the use for which it is intended). In a word the true theory of ammonia having been discovered by Baron Liebig, and its practical importance as an element in manure having been established by Mr. Lawes, there is no further question for the scientific agriculturist on this subject.

It is not admitted by Liebig, on the other hand, that there is any such special action of phosphate on roots as has been suggested by Mr. Lawes; and the fact of a remarkable increase of the turnip crop, apparently resulting from its use, is either attributed to the particular deficiency of this element on Mr. Lawes's land, or is asserted to be entirely due to other causes. What these other causes are, or what is the actual peculiarity of Mr. Lawes's land has neither been proved nor attempted to be proved. I will return to this question of phosphates at the close of these remarks. First, let us dispose of ammonia.

Collateral Evidence as to Ammonia.

After all that has now been said by the combatants on both sides, and their substantial agreement, nothing is likely henceforth to shake the practical conclusion now established as to the immense importance of supplying ammoniacal salts, or nitrogen in some other form, especially to the wheat crop. It is idle to discuss the verbal question whether the value of the ammonia is to be measured by the available minerals in the soil, or whether the value of the minerals is to be measured by the added ammonia. It is time to have done with these personal questions. If, however, in any case there is good reason to suspect the deficiency of the required mineral elements in a soil, by all means let them be added. But when they have been added it is clear that ammonia will still be required to make them available to the plants.

There is, moreover, this great practical difference probably existing between mineral and ammoniacal manures, which must be borne in mind when we cherish hopes of finding out by analysis of the ashes the exact wants of a plant. For some reason not clearly explained, it appears that a large amount of mineral elements may actually exist in a soil, and seemingly a superfluous supply may be added without the plant being able to feed upon them, whereas a very small amount of ammoniacal salt produces a great effect, so great that if it be added in excess, it is likely to endanger the vitality or health of some plants. Consequently the endeavour to supply the mineral conditions when they are wanting (except in case of phosphates to be presently noticed), seems to involve practically the formation of a new soil; this must always be attended with great expense, and till we are better informed as to how to set about it it may be given up as a hopeless undertaking, because we are groping in the dark. Whereas, if we pursue the path pointed out by experience, and select for cultivation those plants, and those varieties of plants which appear to suit the soil and climate, our course is clear, viz. to develope the resources of the soil, as we find it, by the best possible tillage, and by as free use as possible of vegetable and animal manure, until we can obtain in some cheaper form the elements of fertility, for the sake of which practice, unconscious of the reason, has learnt to value these manures.

I say that our course is to develop the resources of the soil by the best possible tillage; it is in connexion with this subject that the experiments of Mr. Smith of Lois Weedon, on the growth of wheat without manure, are so very instructive. It need hardly be repeated here that Mr. Smith divides his corn-fields into beds or sections of 5 feet wide each; and in the centre of each he grows three rows of wheat occupying 2 feet, and leaving a space between these three rows of wheat and the next three rows, 2 feet being covered with wheat, and 3 feet uncovered; the alternate spaces to the width of about 2½ feet between the spaces covered by growing wheat are trenched while the wheat is standing; and that he has added no manure, mineral or atmospheric; the result being that he grows annually 34 bushels per acre on half his land, and this he has now done for twelve years in succession.

Now, although Mr. Smith tells us that when wheat was selling at 5*s.* a bushel he made a profit of 7*l.* per acre, it is not with a view of recommending West of England farmers to adopt his plan that I refer to it, but for the sake of the insight into the laws of nature to be gained by such facts, and especially into the power of the soil to feed itself with ammonia, if it be properly broken up and exposed to the action of the atmosphere. It must in candour be admitted that, in one point of view, the facts of Lois Weedon support Baron Liebig's doctrines. They show that when the mineral food of plants is abundant, if by good fallowing, weathering, or tillage, we can change the dormant into available minerals, we are not obliged to give an artificial supply of ammonia to get a good crop of wheat. On the other hand there is nothing to show that an addition of a dressing of guano, or of nitrate of soda, would not have increased the crop. Here then the farmer may at least learn the vast importance of good tilth on clay soils. On the other hand Mr. Smith's experience gives no sanction at present to the doctrine that such soils as that of Lois Weedon are in steady process of exhaustion, or that they are likely to fall below the point of bearing a maximum wheat crop for centuries to come.*

There is another subject of which at present we know little, namely, the amount of ammonia locked up in the soil at considerable depth; some curious facts were brought to light by Professor Way in his paper on lime, to which the reader may be referred.†

Nor is it requisite to do more than recall the attention of the practical farmer to the principles established by Mr. Thompson and Professor Way, as to the absorbent power of soils by which a well drained clay is enabled to pass a great quantity of rain charged with ammonia, through the staple soil, deducting and detaining the ammonia on its passage in a state sufficiently fixed

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* "Mr. Smith has conferred a benefit on agriculture, by proving that much of the money which is now expended on guano and other extraneous manures may be spared by that careful and complete subdivision of the soil which is so well carried out in the Lois-Weedon system. He has also shown that there are certain soils in this country in which a much greater breadth of wheat can be grown than is generally supposed, because instead of a five years' rotation, which would be equivalent to the setting apart one-fifth of the farm for wheat, one-half may be properly cultivated each year for that purpose."—*Dr. Daubeny's Oxford Lecture.*

Mr. Smith has very justly remarked, in the preface to his twelfth edition, "that if we set aside the cases of pure clay and porcelain clay the great majority of argillaceous soils contain every mineral element of fertility for the wheat-plant in abundance, that abundance varying according to the quality of the clay itself.

"The clay becomes pulverised and porous, and in a condition to absorb and retain the atmospheric ammonia. Whatever ammonia already exists in the clay remains, and a sufficiency of every inorganic element of fertility is rendered soluble and available to the wants of the growing plant."

† Journal of the Royal Agricultural Society of England, vol. xv. p. 491.

for it not to run off, and yet not too much fixed for the plant to feed upon it. It may be well to mention here that the whole subject of the contents of water passing through drains has been referred by the Royal Agricultural Society to their chemist, Professor Way, who is now engaged in a laborious investigation on the subject, and would, I am sure, be glad to hear from any one who has any facts to communicate.

THEORY OF PHOSPHATE STILL UNSETTLED.

It remains only to refer to the question of the action of phosphate of lime, and this must be done very briefly, and without entering into abstract scientific questions. Chemists have generally attached much importance to the phosphates as an element of manure, and this for two reasons. 1st. Because they are required in the seeds of most plants, especially in wheat, so that without phosphates we can have no bread. 2nd. Because while the alkalies and other mineral constituents are to be found in almost all soils in sufficient quantity for vegetation, the phosphates are very frequently present only in small quantities.

In the year 1847 Mr. Lawes pointed out the special connexion of phosphates with the turnip crop ; he had previously shown that his wheat crop had not been increased by the application of mineral manure (including phosphates) to the same soil.

Liebig, in his 'Familiar Letters,' third edition, published in England, 1851, pointed out to English agriculturists the enormous quantity of phosphates annually withdrawn from the soil and carried into great towns, in the shape of flour, cattle, &c. (he might have added especially common cheese). It is certain, he said, that this incessant removal of the phosphates must tend to exhaust the land and diminish its capability of producing grain ; but in the same volume Liebig, referring to the late Mr. Pusey in a manner which I am sure no one more regrets now than himself, spoke slightingly of the special aptitude of phosphorus for turnips.

Here again we have two sides taken respectively by those who follow the chemist of the farm, and those who follow the chemist of the laboratory. The former (founding their opinions first on Mr. Lawes's experiments, published now nearly ten years ago, and secondly, and still more decidedly on the profitable returns for their own outlay in the purchase of superphosphate of lime) believe that phosphate of lime is a specific manure for turnips. Those who have faith in the Giessen theory, and have not studied the actual habits of living plants, are at a loss to perceive why phosphates should have a specific effect on the growth of roots, in the ashes of which they form a far less proportion than potash and other elements, while they persist in asserting that an addition of phosphate of lime is essential to maintain the crops of grain which are constantly removed from the land, and that therefore the use of phosphate must, or at least ought to increase the crops of corn. Meanwhile, in spite of the Giessen theory, farmers manure their roots with superphosphate, and neglect this manure for their corn crops ;* and these practices, and the reasons assigned for them, have found their way into Germany, are adopted by German farmers, and defended by German chemists, and the authority of the great chemist of Giessen is again called in question.

"The opinions of Mr. Lawes have found an echo in Germany, in the latest work of Professor Wolff:—

"If we compare the facts above mentioned, derived immediately from experience and from numerous field experiments, with the chemical composition of the crops, and with the qualities of the essential constituents of manure which are contained in the produce of a given surface, we acquire the conviction that the exhaustion caused by the cultivation of different crops is in no way directly proportional to the quantity and quality of the organic and mineral constituents present in the crops; and further, that the pure Mineral Theory, founded and formerly defended by Liebig, has not been confirmed by the practical experience of agriculturists."

"Such conclusions," says Baron Liebig, "on the part of a writer on agriculture, would lead one to doubt of the possibility of progress. *The exhaustion* of the soil is declared to stand in no way in direct *relation to the produce obtained from it. That is, the effect* (*exhaustion*) *bears no relation to the* (*exhausting*) *cause.*"

"In the experiments of Mr. Lawes we recognise the facts and observations on which such opinions and such dicta are founded."—*Liebig's Principles*, p. 121.

Dr. Wolff, whom Liebig thus caricatures, is, I am informed, one of the soundest and most practical chemists in Germany. How his statement is to be understood will appear presently.

Liebig does not in his last work devote very many pages (about ten) to the subject of turnips, but he says he will take an early opportunity of considering it again. What he does say is certainly not in the most complimentary style: he says, he will consider one of these "unmeaning practical experiences." That the cause assigned for the results given is "sheer fancy," &c. And, after stating what the results given by Mr. Lawes were, he says:—

"It is impossible to believe that the effect in the seventh year under these

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* It is, however, worth while to notice that, in his last manure circular, Mr. Lawes recommends the use of superphosphate for the barley crop. "The best and cheapest manure that can be used for barley or oats is a mixture of genuine Peruvian guano and superphosphate of lime; two bags of guano $2\frac{1}{2}$ cwt., and one bag of superphosphate 2 cwt., mixed and sifted together, are sufficient for $1\frac{1}{2}$ acres to 2 acres of barley and oats."

circumstances can have depended on the newly-added phosphoric acid, as Mr. Lawes considers."

I confess when I read this passage I felt persuaded that Baron Liebig must have some strong reasons for writing such a sentence, and as his work appeared in England too late in the season for me to attempt any experiments with a view to the connexion between nitrogen and wheat, I felt it to be a duty to prepare a careful experiment, in conjunction with our excellent chemist, Professor Voelcker, for trying over again the effect of phosphoric acid on turnips. I will describe this experiment presently. First let me state what I understand to be the issue raised.

THE POINT IN DEBATE AS TO PHOSPHATES.

Liebig's view, as collected from the course of the argument, by which he attempts to put aside Lawes's facts without even an attempt to explain them, consists chiefly in this:—

That when there is a considerable quantity of phosphate in the land, a further addition of the same element cannot, on abstract grounds of reason, whatever appearance the facts may present, be admitted as the cause of the alleged facts. That inasmuch as a crop of turnips could not take out of an acre more that 50 lbs. of phosphate, and inasmuch as Mr. Lawes applied phosphate at the rate of nearly 400 lbs. per annum for several successive years, there must have remained in the soil a considerable residue of former dressings, amounting to some 2000 or 3000 lbs. per acre, before the additions to which Mr. Lawes attributes such remarkable effects; therefore the effects, if correctly reported, were due to other causes, and not to the recent applications of phosphate to the crop during the years in question.

In this argument Liebig takes for granted that the amount of phosphate required to be diffused through the soil, or to be put into it, may be safely estimated by the amount of the same element removed from the land in an average crop. This assumption is a hasty one, and arises from want of practical acquaintance with details which he has left out of sight.

With somewhat more of force he shows that results equal to those attributed by Lawes to the phosphate were produced by applications of dung, and also of ashes of weeds, in which there would have been barely a sufficient quantity of phosphoric acid to account for a crop at all.

Certainly Liebig would appear to be entitled to infer from these facts, that the application of phosphate was not the only cause at work in producing the result reported by Mr. Lawes.

Now I confess that I am far from thinking that Mr. Lawes's experiments have satisfactorily established a specific action of phosphoric acid on turnips, nor, although the language at first held on this subject may have fairly borne this construction, does it appear that Mr. Lawes maintains this opinion. Still we have the fact of the effect of superphosphate on root crops, nearly general throughout England, to account for.

Perhaps the best solution of this question about phosphates is that suggested to me some time ago by Professor Voelcker, who has paid great attention to the subject, and recently brought forward by Mr. Maskelyne in the 'Saturday Review.' I am the more glad to give the explanation in Mr. Maskelyne's language, because he is a supporter generally of Liebig's view, though far from insensible to the value of field experiments founded on the complex facts of English agriculture. His adoption of the explanation is a homage to the Rothamsted experiments, in the face of Liebig's contemptuous rejection of them as "unmeaning experiences."

"The light which vegetable physiology has already thrown—and which even a cursory glance at the wheat and turnip plants may throw—on the subject of their respective proper manures, is interesting, and tends to remove the apparent anomaly which accumulated evidence regarding these manures may seem to present. The tribe to which wheat belongs is peculiarly leafless; the turnip, on the other hand, expands its well-known abundant surface of leaf to the influences of the atmosphere. The leaf is, as it were, the lung of the plant. At its surface the aërial constituents of the nutriment of the plant are in great part imbibed, and in its substance they are decomposed under the influence of the light, at least in so far as the carbonic acid is concerned. The wheat plant, consequently, and all those allied immediately to it, can attract and assimilate but little of this gaseous food by means of their leaf; while the turnip, like nearly all its congeners of the Brassicaceæ tribe, in its large expanse of leaf, covers the field with a vast absorbent surface, that imbibes and turns into turnip-food the carbonic acid and ammonia of the air which passes over it. But examine the underground feeders of the respective plants, and the relations of their food-collecting powers appear reversed. The wheat-plant, with its deeply and widely penetrating roots and root-fibres, seems to forage in as many cubic feet of soil as the turnip-root penetrates inches. The latter, with its vast abnormally developed bulb, presents a comparatively small, because a globular surface, in comparison with its solid contents, while the diverging rootlets that extend from it are confined to a space very limited in comparison with that through which the wheat-root ranges. To maintain, then, and develope the peculiarly abnormal condition of the cultivated turnip, what are the necessary conditions? Clearly to give to it, concentrated and in abundance, the food which it requires; and that food will not be carbonic acid or nitrogen, except in so far as they may act as solvents and carriers of other food—these the leaf gathers abundantly. It is the mineral ingredients of its ash—which the soil may not contain in large enough amount—that must be so supplied to it; pre-eminently, therefore, phosphoric acid in many soils—alkalies, also, and alkaline chlorides, in many others—lime and sulphuric acid, too, perhaps in some. These must be supplied around the plant in immediate proximity to it. Doubtless, also, the roots of the turnip are less vigorous penetrators of mechanically stubborn soils than are the roots of the cereals, and they thrive, therefore, by preference, in lighter lands than these. It may happen, therefore, that a heavy soil, however rich in the appropriate mineral ingredients of the plant, shall yet resist the lateral extension and development of the roots from the bulb, and, while bearing noble wheat crops, respond but sluggishly to the farmer's solicitations for a field of turnips. But the wheat-plant, to which a spread of leaf is wanting, is compelled in a great degree to fall back on the liquid contents of the soil imbibed by its roots for that supply of nitrogenous and carbonaceous food out of which it is to build at once its albuminous and glutinous, and its ligneous and starchy constituents; and its development in a given time will therefore be dependent on the amount of ammonia which it can so assimilate by its roots. These roots are consequently endowed with an enterprising habit, and with penetrating and searching powers, which we seek in vain in the more helpless unwieldy turnip. They consist of fibres, each of which pierces deep into the soil—and penetrates that soil—literally ransacks it for food—on every side. Obviously, therefore, a smaller percentage of phosphates and other minerals in the soil will suffice for the cereals; not that they want much less of these than the turnip, but that they can go farther to collect them. Hence, too, manures that have been in the soil for one or two seasons, and have penetrated further down into it than the surface, may fall more within the range of the foraging roots of this tribe of plants than manures freshly applied, and therefore only mixed with the upper zone of soil—that zone, in short, in which the turnip grows.—*Saturday Review*, Jan. 12, 1856.

I have quoted the above passage at length, because, coming from an ardent disciple of Liebig's, it is an evidence of the value of the correction of German theories supplied by English practical experiments. It virtually admits the defect of Liebig's mode of handling the subject of agriculture, namely, that of applying abstract reasoning to practical circumstances without taking the trouble to attend to those circumstances in detail. To pass from "the Plant" in the abstract to the particular forms and habits of wheat and turnips is a step in the right direction.

Professor Voelcker has kindly pointed out to me other circumstances which serve to account for the effects of phosphate on turnips, so rashly called in question by Liebig. Of all the important soil constituents, phosphoric acid is the most sparingly distributed, compared with other mineral matters; and therefore an additional supply of it is likely to effect most good when brought within reach of the root-crop. Potash salts are more abundant, and more readily soluble; and for this reason the root-crops are more easily supplied with the potash they want. Phosphate is but sparingly soluble in water charged with carbonic acid. If, therefore, a soil contain only 0·05 of phosphate, and if that phosphate be difficult of solution, it is plain that the rain falling during the early period of the turnip's growth—the middle of summer—can dissolve much less of what is diffused through the soil than it will of that portion of the soil, containing a large percentage of phosphate, which is placed by the drill immediately around the seed, whether in the form of bones, superphosphate, ashes of plants, or farm-yard manure. Distribute this small portion of phosphate through the whole mass of the soil by ploughing, dragging, &c., and it will cease to benefit the turnip-crop to any great extent; and so the paradox contemptuously dismissed by Liebig is accounted for by a patient attention to the facts of the case.

Professor Voelcker also informs me that there are some soils containing plenty of phosphate, but deficient in potash, and that then the addition of potash has a specific effect; while on other soils (silicious) no good crop of turnips can be realised with superphosphate alone, because potash is deficient; but if this be supplied in farm-yard manure, the addition of superphosphate produces an immediate effect. These considerations are all consistent with Liebig's fundamental principles.

In addition to these explanations, it may, however, still admit of an inquiry, whether there may not be some effect on the constitution of the plant in its early cell-formations, which, if not produced at once, is irrecoverable afterwards; the turnip-seed being very small, and having therefore a scanty store of ready-made food laid up in itself, may require an immediate and early supply of infant's food, so to speak, for the first radicle and seed leaf; and there may be other causes at work. But the fact is clear, that on English soils (very few excepted) the turnip-plant makes a special demand on the soil for phosphoric acid, and that if this be not supplied in a finely-divided state to the plant during its infancy, its subsequent power of growth is diminished, and the crop of roots is proportionally small.

The consideration of these details, in reference to one tribe of plants, brings us to the general lesson to be learnt from a review of the controversy on which we have been engaged. If, on the one hand, scientific meu have erred in hasty application of general principles, how great need is there for the accumulation of facts well and carefully observed!—will practical farmers assist in this work? So only can steady progress be made in the science of agriculture.

Far be it from the writer of this paper to flatter the ignorance and indolence which will dismiss the brilliant discoveries of the finest intellects as unworthy of a moment's attention, while any circumstance that has a tendency, as it is called, to keep up the market, commands the liveliest interest. He would, on the contrary, most earnestly impress on young men the importance of qualifying themselves and their children, by early education, by awakened interest in general knowledge, and sound judgment, to take an active part in such questions, by adding their practical observations to the stores of knowledge already laid up.

Let us consider for a moment one or two results of the labours of the last few years; first, in the way of scientific principles; secondly, in the way of profitable result to the practical man.

SOME SCIENTIFIC PRINCIPLES SETTLED; SOME STILL IN DOUBT.

We have gained an accurate knowledge of the component parts of all the plants required for the food of man and beast. We know in what they are alike, in what they differ; what they *can* derive from the atmosphere, what they *must* derive from the soil. We know something of the constitution of soils and of the causes of the difference between fertile and barren soils, and we know with tolerable certainty the component parts of the atmosphere.

On the other hand we know as yet but little of the life of plants, and therefore little of the means of controlling and directing the healthy development of the plant,—little, that is, beyond what has been handed down from generation to generation as to the method found by rough blind experience to answer best on each particular soil. How entirely, for instance, are we in the dark as to the causes of corn being laid! It is commonly assumed that the standing up of corn depends on silica, because it is known that silica is contained in straw, and that silica in the form of glass is stiff and hard; but Professor Voelcker has drawn my attention to the fact that this has never been proved, and that it is quite possible that the toughness and elasticity of the stalk is dependent on other causes: and yet on the faith of the analyses of wheat ashes, we have been repeatedly told that by the application of silicates of lime to the soil we shall stiffen the straw,—but who has succeeded in the attempt to do it?

Up to the present time, then, we may say that science has taught clearly some of the demands made by plants, but little as to the means of supplying those demands, while other wants are still unexplained. It has registered and arranged many facts; it has traced, though with less success perhaps, the connexion between those facts. But as a child will be more successful in pulling a watch to pieces in order to examine its parts than in putting it together again and making it go, so we are in the same condition scientifically. Our farming watch (which the dandies are apt to call an old turnip) is a good one—rather old fashioned—but a little out of order; it wants regulation and cleaning. Science makes brilliant offers of new watches in exchange for old ones: when science has proved its skill by showing us a new watch made on scientific principles "that really will go," we shall have great pleasure in handing over the old watch to be pulled to pieces; but for the present, however reluctantly, we must stand by the old clockmaker.

On the other hand it is evident that if agriculture is to satisfy the demands of the people for food, and at the same time to make a profitable return for the investment of capital, it must continue to make advances; and looking at the accumulation of practical knowledge made during the last twenty years, it seems probable that the chief hope of further progress consists in a more intelligent comprehension of the grounds and reasons of inherited practice. For as to improvement in practice discovered by mere chance, there is little to expect in that way; the ingenuity of practical men has been called out to the utmost by the hope of gain under high prices, and by the dread of ruin under low prices. All that can be learned by one district from the practice of another has been made widely known by Mr. Pusey's labours in the great English Journal, so that what we now want is a fresh start founded on knowledge and comprehension: knowledge of all the facts handed down from our ancestors, as well as stumbled upon in our day; comprehension of the natural laws, which, if known, would give us the reasons of those facts.

We are thus arrived at a point in the history of Science and Practice at which progress is impossible without a hearty co-operation between both.

The chemist has worked hard, very hard; in his own department he has made immense progress. If he has failed in his application of his knowledge to practical business the fault is not all his own. What has the practical man done to help him? Very little, except, as I said before, laugh at him, and now and then invite him to dinner.

One Practical Point at least established.

I have alluded to the general principles recently worked out. Let us glance for a moment at one of the practical benefits conferred by chemical inquiry on the farmer within a quarter of a century. At the beginning of that period we may say that no answer could be given to the questions — why does dung benefit our crops? is all its bulk wanted? or do we incur the heavy cost of carriage only for the sake of certain portions of it?

Now we may say that the answer has been given, not, it is true, by pure chemistry alone, for that dazzled our sight, and led us astray for a while, but by the chemistry of practical farming, that is, by the facts of real farm practice carefully examined by Mr. Lawes and Dr. Gilbert in combination; a country gentleman and a manure manufacturer acting in concert with a pupil of Liebig's.

And what is the answer given? A most important one for the practical farmer as a guide in his manure purchases. It is now clearly established by the combined evidence which results from the cross questioning of the two chief witnesses, Liebig and Lawes, that on the ordinary soils of England nitrogen and phosphorus are the two chief elements of manure to which the farmer must direct his attention as a purchaser. Nitrogen may be in the chemical state of nitric acid or of ammonia; phosphorus, as phosphoric acid, in the form of superphosphate or soluble phosphate.

On certain soils there may be peculiarities requiring special consideration, as, for instance, on some of the strata of the West of England the application of lime, especially on pasture land, seems almost indispensable to the sweetness of the grass. It is not quite clear that this effect can always be accounted for by a deficiency of lime in the subsoil; but the utility of lime in certain cases is undoubted. Probably the use of sea sand in Cornwall rests on the same foundation.

But in the ordinary course of cultivation on mixed soils there can be little room for doubt, that the farmer need never trouble himself to send his carts to market for any manurial constituents except those two above indicated. It is obvious that, if this be true, and if the farmers generally are satisfied of its truth, the manure dealers must very soon adapt their supply to the demand.

Let the purchaser steadily refuse to be guided by vague testimonials, and compel the manufacturer to bring up his manure to a given standard of nitrogen and phosphate in a proper state, and the fraudulent dealer will be driven out of the market; the manure business must then pass into the hands of men of capital, who have the means of purchasing the raw materials on the best terms, and the mechanical appliances for working them up at the lowest cost and in the best state. Good manures will then spread over the country through respectable agents, and pass into the hands of retail dealers, just like Bass's pale ale, Price's candles, or any other marketable commodity from a well-known firm.

This advantage, then—viz., a practical check on the frauds of the manure market—has been put into the hands of the farmer by the chemist: first, by the broad general principles established and diffused by Liebig; secondly, and still more specially, by the correction of these general views by Lawes. This advantage is already fully appreciated and used by the most intelligent and practical agriculturists, especially by those who, on our Council and elsewhere, have come into personal communication with our excellent Professor Voelcker. It remains to diffuse through every corner of the West of England this confidence in the practical results of accurate knowledge well and cautiously applied to the facts of our climate.

Lectures, Collection of Facts.

Two steps have been taken by the Council of our Society with a view to this object: the first has been eminently successful so far; of the second a word in conclusion, and then I will relieve the reader. The first step has been the delivery, by Professor Voelcker, of several lectures in some of the principal market towns of the West of England. These lectures have been well attended, and have elicited some useful discussion. The substance of some of these is printed, for the general information of the members, in the present number of our Journal.

The other step referred to was an attempt to collect facts in our own district from practical men, with a view to a "proposed Report on manures on sale in the West," as explained in the Report of the Chemical Committee. For this purpose, our zealous assistant-secretary, Mr. Roberts, sent out about three hundred copies of the Circular, together with the form of return in which every attempt was made to save trouble to those from whom information was sought. In fact, the request of the Committee to three hundred of the most intelligent agriculturists in the West of England (and where are we to look for better?) amounted to these two simple questions—"Will you send us a sample of any manure you have purchased this season?" "Will you tell us how it answered, well or ill?" The object was to show how far the practical effect in the field corresponded with the analysis of the chemist; in short, to give confidence in analyses if supported by the facts; and, if not supported by the facts, then to obtain the means of supplying the corrective. The Council voted a handsome sum of money for the analyses of the manures, therefore there would have been no expense to the members. Well, it was a very bad season for the trial of artificial manures, and the plan suggested for the collection of information was rather a novel one; so perhaps the less said about its results the better We will hope for a better crop of experiments, as well as of turnips, this year. All communications will be welcome, however trifling.

Meanwhile I beg leave to lay before the reader my humble contribution to the progress of practical science in the form of the following Report, which, if it be not an example to imitate, may serve as a buoy upon the shoals to be avoided.

Report of an Experiment on Killerton Farm, made with a view to test the effect of Phosphates.

BUT few words are necessary to explain the purport and intention of the experiment on which I have to report. As to its results, they are as I expected they would be, for the first year, next to none. Perhaps however the time spent will not have been quite useless if those engaged in it have gained some experience, and if a hint is given to others as to a few of the conditions requisite to try an experiment in such a way that any conclusions can be founded upon it. The plan of the experiment was laid out with a view to meet some of Liebig's criticisms on Lawes's turnip experiments, and especially that by which he attempts to show that the increase in Lawes's turnip crop could not be owing to the phosphates applied to it.

Bearing in mind the course of Mr. Lawes's inquiries the reader will perceive that the questions put to the field are the following:—

Has phosphate of lime any effect on turnips * in this field?

Has it more effect when it is drilled with the seed than when it is broadcast?

Has it more effect when obtained from burnt bones than from mineral phosphate (apatite)?

Is there any ground for supposing that the effect of superphosphate is in any measure due to sulphuric acid, or will it have the same effect when dissolved in muriatic acid?

Does the addition of ammonia, or of potash, or of both together, increase the effect?

The manures were each applied at the rate of 2 cwt. per acre, and mixed for the drill with sand from an adjoining sand pit; on the strip with no drilled manure, sand alone was drilled to make doubly sure, and curiously enough this strip seemed to come up the quickest.

Beginning on the right hand, a strip from east to west was manured with some pure phosphate made from apatite by Lawes, broadcast, or rather flung loosely over the seed by hand in the direction of the drill mark. The next strip has no phosphate. The third, Lawes's apatite drilled with the seed. In the two last strips to the left, was drilled phosphate, free from ammonia, made of burnt bones expressly for this experiment, and prepared for me by Messrs. Burnard and Lack, in one case with muriatic acid, and the other with sulphuric acid. The cross-dressings were sulphate of ammonia and sulphate of potash, and the two mixed; 2 cwt. of each separately, and 1 cwt. of each in the mixture (per acre).

* The kind of swedes sown was the *Purple Top*, obtained from Messrs. Veitch, of Exeter; they were drilled on the 28th of June.

EXPERIMENTAL FIELD on Killerton Farm, to test the effect of Phosphate alone, and in combination with Ammonia and Potash.

E
N—|—S
W

(Crop, Swede Turnips) 1855.

Ground slopes to the west.

This (Eastern) part of the field was manured with dung, and was twice eaten off by the fly.

Four rows of Turnips, with no Manure either way. (North side)

Ammon. Bone and Sulph. Acid. The part adjoining the dung eaten off by the fly. (Not weighed.)	Ammon. Bone and Muriatic Acid.	Ammon. Phosph. drilled.	Ammon. O ↓	Ammon. Phosph. broad-cast.	Cross-Dressing with Ammonia; not weighed.
O→ Bone and Sulph. ↓ 12¼ tons.	O→ Bone and Muriat. ↓ 12½ tons.	O→ Phosph. drilled. 11¼ tons.	O O ↓ 12¼ tons.	O Phosph. broad-cast. 12½ tons.	No Cross-Dressing; Average 12 tons.
Potash. Bone & Sulph. Acid. 14⅜ tons.	Potash. Bone & Muriat. Acid. 14¼ tons.	Potash. Phosph. drilled. 13¾ tons.	Potash. O 12¾ tons.	Potash. Phosph. broad-cast. 13¼ tons.	Crossed with Potash; Average 13¼ tons.
O— Bone and Sulph. 12½ tons.	O— Bone and Muriat. 12 tons.	O— Phosph. drilled. 10¾ tons.	O—O 12½ tons.	Phosph. broad-cast. 12¾ tons.	No Cross-Dressing; Average 12½ tons.
Ammon. and Potash. Bone & Sulph. Acid. 13¾ tons.	Ammon. and Potash. Bone and Muriat. 13¾ tons.	Ammon. and Potash. Phosph. drilled. 12¼ tons.	Ammon. and Potash. O 13 tons.	Phosph. broad-cast. 13¼ tons.	Crossed with Ammonia and Potash; Average 13¼ tons.
O— Bone and Sulph. 13½ tons.	O— Bone and Muriat. 13¾ tons.	O— Phosph. drilled. 12¼ tons.	O— O 13¼ tons.	O— Phosph. broad-cast. 13 tons.	No cross dressing. Average 13 tons.
Ammon. Bone and Sulph. 13¼ tons.	Ammon. Bone and Muriat. 15½ tons.	Ammon. Phosph. drilled. 14 tons.	Ammon. O 13¼ tons.	Ammon. Phosph. broad-cast. 13¾ tons.	Crossed with Ammonia. Average 14 tons.
O— Bone and Sulph. 12¼ tons.	O— Bone and Muriat. 14 tons.	O— Phosph. drilled. 13 tons.	O— O 13 tons.	Phosph. broad-cast. 13½ tons.	No cross dressing. Average 13 tons.
Potash. Bone and Sulph. 13¼ tons.	Potash. Bone and Muriat. 14 tons.	Potash. Phosph. and drilled. 13½ tons.	Potash. O 12½ tons.	Phosph. broad-cast. 13 tons.	Crossed with Potash. Average 13¼ tons.
O— Bone and Sulph. 11 tons.	O— Bone and Muriat. 11½ tons.	O— Phosph. drilled. 11¾ tons.	O—O 10 tons.	Phosph. broad-cast. 9¾ tons.	Near the hedge. Average 10¾ tons.

Four rows of Turnips, with no Manure either way. (South side)

On the South side a Grass Field adjoining. No Hedge.

A thick hedge at the bottom of the Field (West).

Burnt Bones and Sulphuric Acid, drilled, produce 80 cwts., or 13¼ Tons per Acre.	Burnt Bones and Muriatic Acid, drilled, produce 83¼ cwt., or 13¾ Tons per Acre.	Lawes's Phosphate (Apatite) drilled, produce 77½ cwt., or 12¾ Tons per Acre.	No Phosphate at all, produce 77¼ cwt., or 12¾ Tons per Acre.	Lawes's Superphosphate broadcast, produce 79¼ cwt., or 13¼ Tons per Acre.	.... Total Weights on Forty-eight Perches, omitting the spots adjoining the Hedge.

To save the reader trouble I have marked on each compartment the combination of manures produced by the crossing, and the rate per acre of the crop calculated from the actual weighing. I have also carried out the total of each strip in the margin. The margin on the right hand shows the result of the cross-dressing on 40 perches (quarter of an acre), the whole being weighed. The margin at the foot shows the result of the columns of phosphate, calculated on 48 perches, all weighed. Where either manure is omitted it is indicated by an O. Where both the drilled manure and the cross-dressing are omitted the fact is indicated by O O.

The reader will draw his own conclusions from the Table. My own opinion is, that the field has given no answer to any of the questions, and for this reason: if you look at the spots wholly unmanured, marked with double O O, it will be seen that in almost every case the unmanured spot stands as well as its surrounding neighbours. Again, comparing the whole column in which there was no phosphate with the other four taken each as a whole, the largest difference is 1 ton per acre. Taking again each of the lines from right to left as a whole, and comparing the lowest amount on one of the lines on which there was no cross-dressing with the highest amount, viz. that on the line cross-dressed with ammonia, the difference is only two tons.

From such results I think no conclusions are to be drawn. What we have obtained is a carefully-made examination of the present state of each part of the field, and I think the evenness of the results is the most satisfactory point gained as a datum level for any future experiments. Mr. Dymond will notice, I am sure, with satisfaction, that by far the lowest results are due to the proximity of a real Devonshire hedge on the western side of the field.

I will now state shortly the plan on which the experiment has been conducted. The field is very good land; in this there are some disadvantages and some advantages. The soil is a deep free loam, rather heavy at the lower or western end; the spot selected is free from hedges and trees, except on one side; but on two sides it is bounded by a railing, which is convenient as a means of access for inspection. The large squares marked out are exactly 8 square perches, consequently just $\frac{1}{20}$th of an acre, and therefore cwts. may be read off in weighing as tons. The smaller spots are just half this size, which was thought large enough for unmanured spots. But I attach great importance to having unmanured spots at intervals in different parts of the field. They are a check upon each other, and upon every other part of the work. The cross-dressings are also in duplicate, consequently they check each other, and guard against accidents.

For instance, one strip manured by ammonia was eaten off by the fly; had it not been repeated in a lower part of the field, there would have been no record of the effect of the ammonia. It is remarkable, speaking of the fly, that its ravages extended wherever dung was used, and for a few yards beyond; on the part manured with dung the sowing had to be repeated three times. All the rest of the field came up evenly, though slowly, the weather being very dry after sowing.

The *whole* of the roots were weighed and drawn off the ground; we began weighing the leaves, which were also drawn off, but the weights were so uniform that it seemed useless labour to go on. Consequently the spots weighed, when taken together, are considerable: for instance, the two parts cross-dressed with potash amount to half an acre; each of the strips treated with phosphate exceeds a quarter of an acre. The parts absolutely without manure amount to the eighth of an acre, and four drills were reserved on each side, without manure, in case of accident. Such precautions are not very troublesome, and without them there is sure to be disappointment or fallacious results.

As to former treatment, the field was never used to over-feeding; it came into hand about four years ago, after a long course of bad farming, during which it had little dung, and no artificial manure. Since it has been in hand it has only had one moderate dressing of guano; the chief business has been to get it clean. The former crops have been turnips, barley, clover, wheat.

It is evident that the artificial manures this year had very little effect; dry weather came in soon after the sowing, and the season has altogether been against turnips; on another part of the field, well dressed with dung, the crop did not exceed 15 tons, and a neighbour who always has fine root crops, if it is possible to have them, had about 14 tons.

The field is now sown with Buff wheat sown early in March; it is my intention to pursue nearly the same course of manuring year after year on an alternate rotation of corn and root crops, drawing all off the land and returning nothing. Mr. Lawes and others have grown wheat in succession year after year, and roots in similar succession. I think there may be some good in pursuing a similar course with alternate crops, only I shall probably confine the cross-dressing to nitrogenous manures, salts of ammonia, and nitrate of soda, and substitute a mineral manure expressly prepared on Liebig's supposed principles for one of the rows of phosphate.

Report of an Experiment on Wheat with Mineral and Nitrogenous Manures.

IN the fourth volume of the Bath and West of England Society's Journal, p. 276, I wrote a short report of an experiment on Killerton farm made with a view to test the effect of phosphates on turnips in 1855.

I stated that I intended to carry on the experiment with an alternate rotation of crops, and that the field was sown with wheat in March, 1856. The turnips were all carted away.

The plots were laid out in the same way as in 1855. By reference to page 277 of last year's Journal, and noticing the spaces marked with O and O O, it will be easy to identify the spots. The top strip A, 1, 2, 3, 4, 5, was not in the page last year.

It should be noticed that on the strip A (which is above the average) the turnips were eaten off by the fly in 1855, and that a part of the field was injured by carting off the turnips; the parts so affected are denoted by asterisks (*), which indicate the cart track also.

Beginning on the left hand of the page, the column headed by the number 1, running from east to west, was manured with 1 cwt. of pure minerals, specially prepared under my direction,* after consulting Professor Way, by Messrs. Burnard and Lack on Liebig's principle of supplying the mineral matter of the wheat; the quantity is more than ample.

Column 2 was manured with ¾ of a cwt. of the mineral mixture, and ¾ of a cwt. of soluble silica kindly supplied by Mr. Paine for the purpose.

Column 3 with the silica alone.

Column 4 had no manure either in 1855 or 1856.

Column 5 had Lawes's phosphate applied to turnips in 1855, but no manure in 1856.

Taking now the strips from left to right, indicated by letters—

The strips A, C, E, G, I, L, received no cross-dressing, consequently at the plots at which these strips crossed column 4 the field was absolutely unmanured for two years, having, as I stated last year, never been much used to high feeding; the six spots marked O O, therefore are intended as a check on the condition of the field by nature, but, as I shall show presently, even this check was not sufficient.

Strips B and H were manured with sulphate of ammonia at the rate of 2 cwt. per acre; strips D and K were manured at the same rate with nitrate of soda; strip F with guano at the rate of 1½ cwt. per acre.

* It must be understood that the manure was not recommended by Messrs. Burnard and Lack, but only made on purpose for the trial of one particular point.

Size of the Spots B, D, F, H, K, 8 perches, or $\frac{1}{20}$th of Acre; the others 4 perches.	Experimental Field, See Journal Vol. IV. p. 227. (Crop, Buff Wheat, 1856).	Ground slopes to the West.	E N—|—S W	Produce of 40 perches and 20 perches alternately in lbs., and rate per Acre in bushels.

On the South side a Grass Field adjoining. No Hedge.

	1.	2.	3.	4.	5.	
A	lbs. 102 Straw. 52 Corn. O 12 Chaff.	lbs. 93 Straw. 50 Corn. O 11 Chaff.	lbs. 96 Straw. 47 Corn. O 12 Chaff.	lbs. 85 Straw. 41 Corn OO 13 Chaff,	lbs. 65 Straw. 29 Corn. O 10 Chaff.	No Cross-Dress[g] Corn 219 lbs. 29 bu. 1 pk. per Acre.
B	lbs. 192 Straw. 109 Corn. 13 Chaff.	lbs. 152 Straw. 85 Corn. 15 Chaff.	lbs. 182 Straw. 96 Corn. 15 Chaff.	lbs. 141 Straw. 79 Corn. 13 Chaff.	* lbs. 122 Straw. 64 Corn. 12 Chaff.	Cross-Dressing, 56 lbs. Sulph. Am. Corn 433 lbs. 28 bu. 3½ pk. p. A.
C	lbs. 87 Straw. 48 Corn. O 10 Chaff.	lbs. 76 Straw. 43 Corn. O 9 Chaff.	lbs. 59 Straw. 30 Corn. O 8 Chaff.	lbs. * 44 Straw. 21 Corn. OO 7 Chaff.	lbs. 48 Straw. 23 Corn. O 5 Chaff.	No Cross-Dress[g] Corn 165 lbs. 22 bu. p. A.
D	lbs. 214 Straw. 118 Corn. 12 Chaff.	lbs. 183 Straw. 95 Corn. 14 Chaff.	* lbs. 155 Straw. 80 Corn. 10 Chaff.	lbs. 159 Straw. 81 Corn. 15 Chaff.	lbs. 147 Straw. 72 Corn. 12 Chaff.	Cross-Dressing, 56 lbs. Nit. Soda. Corn 446 lbs. 29 bu. 3 pk. p. A.
E	lbs. 61 Straw. 33 Corn. O 8 Chaff.	lbs. 42 Straw. 21 Corn. O 6 Chaff.	lbs. * 42 Straw. 20 Corn. O 5 Chaff.	lbs. 45 Straw. 27 Corn. OO 5 Chaff.	lbs. 45 Straw. 23 Corn. O 4 Chaff.	No Cross-Dress[g] Corn 124 lbs. 16 bu. 2 pk. p. A.
F	lbs. 182 Straw. 101 Corn. 16 Chaff.	lbs. 134 Straw. 88 Corn. 16 Chaff.	* lbs. 120 Straw. 65 Corn. 14 Chaff.	lbs. 140 Straw. 75 Corn. 15 Chaff.	lbs. 139 Straw. 65 Corn. 14 Chaff.	Cross-Dressing, 43 lbs. Guano. Corn 414 lbs. 28 bu. p. A.
G	lbs. 60 Straw. 29 Corn. O 6 Chaff.	lbs. * 55 Straw. 31 Corn. O 7 Chaff.	lbs. * 47 Straw. 26 Corn. O 6 Chaff.	lbs. 56 Straw. 29 Corn. OO 5 Chaff.	lbs. 71 Straw. 34 Corn. O 6 Chaff.	No Cross-Dress[g] Corn 149 lbs. 17 bu. 3½ pk. p. A.
H	lbs. 175 Straw. 95 Corn. 14 Chaff.	* lbs. 163 Straw. 80 Corn. 16 Chaff.	lbs. 177 Straw. 87 Corn. 14 Chaff.	lbs. 162 Straw. 86 Corn, 15 Chaff.	lbs. 203 Straw. 95 Corn. 13 Chaff.	Cross-Dressing, 56 lbs. Sulph. Am. Corn 443 lbs. 29 bu. 2 pk. p. A.
I	lbs. 46 Straw. 19 Corn. O 5 Chaff.	lbs. * 52 Straw. 22 Corn. O 7 Chaff.	lbs. 64 Straw. 34 Corn. O 6 Chaff.	lbs. 68 Straw. 36 Corn. OO 6 Chaff.	lbs. 69 Straw. 39 Corn. O 6 Chaff.	No Cross-Dress[g] Corn 150 lbs. 20 bu. p. A.
K	* lbs. 129 Straw. 60 Corn. 12 Chaff.	lbs. 163 Straw. 79 Corn. 14 Chaff.	lbs. 189 Straw. 91 Corn. 15 Chaff.	lbs. 185 Straw. 93 Corn. 15 Chaff.	lbs. 209 Straw. 95 Corn. 15 Chaff.	Cross-Dressing, 56 lbs. Nit. Soda. Corn 418 lbs. 27 bu. 3½ pk. p. A.
L	lbs. * 49 Straw. 20 Corn. O 6 Chaff.	lbs. 67 Straw. 30 Corn. O 6 Chaff.	lbs. 79 Straw. 43 Corn. O 6 Chaff.	lbs. 83 Straw. 36 Corn. OO 7 Chaff.	lbs. 99 Straw. 48 Corn. O 8 Chaff.	No Cross-Dress[g] Corn 177 lbs. 23 bu. 2 pk. p. A.

A thick Hedge at the bottom of the Field.

	Mineral Wheat Manure.		Minerals and Paine's Silica.		Paine's Silica.		No Manure, 1855. No Manure, 1856.		Phosphate, 1855. No Manure, 1856.		
	bu. p. A.	lbs.	bu. p. A.	lbs.	bu. p. A.	lbs.	bu. p. A.	lbs.	bu. p. A.	lbs.	
	32½	483	28½	427	28	419	27½	414	26	391	Produce of 40 perches in lbs. rate per Acre in Bushels.
	22½	201	22	197	22	200	21	190	21 b. 3 pk.	196	Produce of 24 perches in lbs. rate per A. in Bu.
Total	28½	684	26	624	25 b. 3 pk.	619	25 b. 1 pk.	604	24 b. 2 pk.	587	Total of each Column.

The produce of each plot was carefully reaped and separately thrashed, the results are stated under 3 heads, straw, corn, and chaff. I must lay the facts before the members of the Society without much comment. The effect of the nitrogenous manures is very evident—that of the minerals is not so well tested. I thought I had taken abundant precaution to check the produce of different parts of the field, but I found that the omission of one more check had injured the experiment; it may be observed that there is a somewhat higher rate of produce in some parts of columns 1 and 2 which received the dose of minerals; on my noticing the fact with some surprise to my assistant, I received the satisfactory information that it was always known that that part of the field was rather the best. So difficult is it to carry out an experiment. Had I known this earlier, a strip on the north side of the experiment might have been kept unmanured and the produce weighed separately, as in fact I once intended, and so this estimate of the quality of that part of the field might have been checked.

At the foot of the page is set down the average effect of the mineral manures alone as shown by the number of pounds of corn on 6 plots of 4 perches each; and also the increased produce due to the addition of nitrogenous manures to the minerals on 5 plots of 8 perches each. Each being reduced to the rate of produce per acre in bushels.

On the Question between Lawes and Liebig. Extracted from an Address by Dr. DAUBENY, F.R.S., delivered by him as President of the British Association for the Advancement of Science, at Cheltenham, 1856.

"IT is well known that a controversy has been going on for some time past between this distinguished foreigner* and certain experimental agriculturists of our own country, with regard to the principles upon which the manuring of our land ought to be regulated. In this dispute, however, you will not expect me to take part, for it would be obviously improper on the present occasion that I should avail myself of a little brief authority to influence the public on either side of a much-debated question; and, indeed, on any other it might be deemed an act of presumption in an individual, who can prefer no claim either to the extensive practical experience of the one, or to the high scientific eminence of the other, to take upon himself to adjudicate between two such conflicting parties.

"But I may be permitted to remark, that whilst some points of

* Baron Liebig.

difference between them still remain open for further investigation, a much nearer correspondence of opinion exists with respect to others than the public in general, or even perhaps the disputants themselves, are inclined to allow.

"In so far, indeed, as relates to the relative advantages of mineral and ammoniacal manures, I presume there is little room for controversy; for although most soils may contain a sufficiency of the inorganic constituents required by the crop, it by no means follows that the latter are always in an available condition; and hence it may well happen that in most cases in which land has been long under cultivation, the former class of manures becomes, as Baron Liebig asserts, a matter of paramount necessity. Now that the same necessity exists for the addition of ammoniacal manures can hardly be contended, when we reflect, that at the first commencement of vegetable life every existing species of plant must have obtained its nourishment solely from the gaseous constituents of the atmosphere, and from the mineral contents of the rock in which it vegetated.

"The only divergence of opinion, therefore, that can arise, relates to the degree of their respective utility in the existing state of our agriculture, and to the soundness of Baron Liebig's position, that a plant rooted in a soil well charged with all the requisite mineral ingredients, and in all other respects in a condition calculated to allow of healthy vegetation, may sooner or later be able to draw from the atmosphere whatever else is required for its full development.

"And does not, I would ask, this latter position derive some support from the luxuriant vegetation of the tropics, where art certainly contributes nothing towards the result? and is it not also favoured by such experiments as those carried on at Lois Weedon, in Northamptonshire, where the most luxuriant wheat crops have been obtained for a number of consecutive years without manure of any kind, simply by following out the Tullian system of stirring up and pulverising the soil?

"How, too, are we to explain that capacity of subsisting without any artificial supply of ammonia, which Mr. Lawes is led by his experiments to attribute to turnips, and other plants of similar organization, unless we assume that the power residing in the leaves of absorbing ammonia from the air may render plants, in some cases at least, independent of any extraneous aid?

"Be this, however, as it may, there is at least a wide distinction between this opinion, and the one attributed to Baron Liebig by many, who would seem to imagine, that according to his views, ammonia, if derived from artificial sources, was in a manner useless to vegetation.

"As if it could be a matter of any moment, whether the substance which in both cases afforded the supply of nitrogen, and which in both cases also was primarily derived from the decomposition of organic substances, had been assimilated by plants directly upon its being thus generated, or had been received into their system at a later period, after having been diffused through the atmosphere! To suppose that Baron Liebig should have attached any moment to this distinction seems inconsistent with many passages in his work, in which, although the paramount importance of mineral manures may be insisted upon, and the success which had in certain cases attended the use of one compounded only of mineral ingredients may be put forward as a motive for further trials, the utility of ammoniacal substances in all their several forms is at the same time distinctly admitted.

"Still the practical question remains, whether, admitting the theoretical truth of Baron Liebig's position, a larger expenditure of capital * will not be required for bringing a given farm into a condition to dispense with ammoniacal manures, than for procuring those materials which contain that ingredient ready for use. And here experimental researches, such as those conducted on so extended and liberal a scale by Mr. Lawes and Dr. Gilbert, come in aid of theory. They stand, as it were, midway between the abstract principles which science points out to the farmer, and the traditional usages with respect to his art, which have been handed down to him from one generation to another. They bear the same relation to the farmer, which the records of the clinical practice in a large infirmary do to the general principles of medicine expounded by the modern physiologist.

"It is true, that the experience of a particular hospital may not at all times coincide with the anticipations which science holds out; but this discrepancy only suggests to us the imperfection of our present knowledge, and is not allowed to disturb the confidence of the physician in principles already established on incontrovertible evidence. On the contrary, whilst he modifies his practice from time to time by the experience he has gained by actual observation, he feels at the same time the fullest conviction, that these results will be found eventually reconcileable with the general principles, which a still more extended series of inductions may have established.

"I need not occupy your time by applying the same method of proceeding to the recent researches alluded to, but I will carry the analogy between the science of Agriculture and of Therapeutics one step further. You may recollect, that in a Report on the progress of husbandry, drawn up some years ago by one

* This is the whole question for agriculturists; and, as far as we know at present, it is not limited to particular soils, at least in England.—ED.

of the most enlightened and zealous promoters of the agricultural interest in Great Britain, now, alas! deceased, it was asserted, that chemistry had done nothing for the farmer, except in teaching him to use sulphuric acid with his bones, and to take advantage of the refuse flux liquor, formerly thrown away and wasted.

"Now a statement of this kind, although it might be literally true in the narrow sense in which the author doubtless intended it, namely, as referring merely to the introduction of new specifics or recipes into farming, was calculated, when put forth on such high authority, to foster that tendency in the human mind to which we are all more or less prone—that of sparing ourselves the trouble of thought and reflection in shaping the course of our conduct, by leaning blindly upon certain rigid and unvarying rules already chalked out to us by others.

* * * * * * *

"Grant that Science has as yet supplied us with only two infallible receipts for the improvement of our land, the agricultural chemist may derive credit from the reflection, that medicine too, since the days of Hippocrates, has lighted only upon two or three specifics for the cure of disease; and that the most enlightened physicians of the present day, in the spirit which we would fain see actuating the leaders of the agricultural body, depend not upon the efficacy of *nostrums*, but upon their sagacity in referring the varying conditions of each case which comes before them to those principles of physiology which modern Science has established.

"And has not Science also unfolded principles which may be called in to aid and direct the practical labours of the agriculturist?

"I need not go further than the works of Baron Liebig for an answer to this question. I may appeal, for instance, to the extensive employment of guano at the present time, first introduced in England in consequence of his suggestions: I may refer to the substitution of mineral phosphates for bones, founded upon his explanation of the sources from which the latter substance derives its efficacy as a manure: and I may allude more especially to his refutation of the humus theory, to which even the great Saussure gave his adhesion, and the reception of which was calculated to vitiate, not a few processes only, but the entire system of our husbandry.

"But whilst we do justice to those comprehensive views on agricultural science which have shed a new lustre upon the name of Liebig, let us not forget the practical researches which have been carried on in our own country; and especially those conducted under the auspices of the Highland Society by Dr. Anderson; at our own Agricultural College by Professor

Voelcker; and, through the aid of the Royal Agricultural Society, by their consulting chemist, Mr. Way. And, although in alluding to the labours of the latter, we may be bound to confess, that in one of the latest and probably the most important investigations undertaken by him, that namely on the absorptive qualities of clay with reference to ammoniacal salts, he had been anticipated, so far as the principle goes, by the German Professor, who announced the fact many years before in his work 'On Chemistry applied to Agriculture,' * yet experience has often shown that a principle may lie dormant long after it was enunciated, until its truth is rendered palpable to the senses by a series of practical researches expressly directed with a view to demonstrate its general applicability.

"Baron Liebig has himself remarked, that as a plant, in order to thrive, must receive its food, not in a concentrated form, but reduced to a certain state of tenuity by being diffused through water; so an abstract truth only makes an impression upon the mind and feelings, when presented to it properly diluted, turned, as it were, inside out, examined under every aspect, and decked out with all the accompaniments of dress, ornament, and colour.

"Then, indeed, as the seed, when implanted in the ground and taken root, is able to cleave asunder the hardest rocks, and that, as the old proverb says, all without noise; so likewise the truth will at length in its own good time begin to germinate, and gradually conquering all obstacles, establish for itself a footing in the mind of the public. Let us not therefore withhold our meed of approbation from those who have worked out for us any useful scientific principle, even though the germ may be traceable to some other quarter; conscious that it is to its being brought thus prominently forward, and, as it were, forced upon the attention of the public, that we owe its general reception and its reduction to practice."

An attempt was made in the fourth volume of the Bath and West of England Journal to state fairly the result of the controversy between Baron Liebig and Mr. Lawes in its practical bearing on the farmer's business. A hope was then expressed † that Dr. Daubeny (though his name was not mentioned) would sum up the question, holding the balance even between science and practice. Dr. Daubeny has spoken from the high station of the Presidential Chair of the British Association; and it is due to him and to our readers to lay his judgment before them.

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* P. 57, Eng. Trans.

† See above, p. 54.

At the same time it may be permitted to one who is not a professed scientific man to express the opinion that the distinguished foreigner who inscribed his last vehement attack on our English experimentalist, Mr. Lawes, to Dr. Daubeny, is greatly indebted to Dr. Daubeny for what would be called in a court of justice a very favourable charge.

Nevertheless, Baron Liebig's claims to be the great authority in agriculture, which he has long been in chemistry, and his reputation for fairness in his treatment of his opponent, will probably remain where they have long been in the opinion of the jury of plain Englishmen and of many distinguished German chemists.

It would be dangerous for the writer to dispute with Dr. Daubeny on a scientific point. But on behalf of Mr. Lawes's practical friends it may be said that they do not deny that in those cases in which the mineral constituents of plants are either exhausted, *or not available*, *or*, which comes to the same thing, *not accessible* by the roots of the plant under the circumstances of the particular crop, such constituents must be supplied: the use of superphosphate for root crops is a case in point.

Still less have they called in question "the soundness of the position" that "a plant rooted in a well-charged soil, with all the requisite mineral ingredients and in all other respects in a condition calculated to allow of healthy vegetation, may *sooner or later* * be able to draw from the atmosphere whatever else is required for its full development."

The English practical men do not dispute the truth of Liebig's abstract principles, but they contend that before practical conclusions can be usefully drawn from them, the habits of particular plants, and the conditions of agriculture as it is, must be more carefully examined; and they complain of his contemptuous treatment of those who have applied themselves to this most useful and laborious branch of the subject. No doubt it is true, as Dr. Daubeny remarks, that there has been throughout less difference of opinion than the disputants are inclined to allow; but neither can there be any doubt as to what was the practical effect on the manure manufacture of the teaching of Liebig and his followers until Mr. Lawes's papers drew attention to the prevalent errors built on the so-called "mineral theory."

Meanwhile the utility of ammonia has been fully established in practice; and Mr. Lawes' manure-circulars show that corn-crops are increased by the application of phosphates, under certain conditions.—*T. D. Acland. May*, 1857.

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