LIEBIG

ON

MODERN AGRICULTURE

LETTERS

ON

MODERN AGRICULTURE.

BY

BARON VON LIEBIG.

EDITED BY

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TO

HIS MAJESTY MAXIMILIAN II.

KING OF BAVARIA.

To the circle of men devoted to Art and Science, whom Your Majesty assembled around you last winter, for the purpose of obtaining from their discourses and their animated interchange of opinions a reflection of the intellectual movement of the age, I am in a great measure indebted for the impulse which led to the researches to which these Letters on Modern Agriculture owe their origin.

If, therefore, I venture, with the most profound respect, to dedicate to Your Majesty, who takes the same kind and active interest in the practical life of the nation and its welfare, as in science and its progress, this Work, which is intended to bring about the union of the natural sciences with agriculture, and to effect their beneficial co-operation, I do so in grateful remembrance of the active and powerful interest which Your Majesty has deigned to take in the labours of

Your Majesty's

Most obedient humble Servant,

JUSTUS VON LIEBIG.

MUNICH, *April* 2, 1859.

EDITOR'S PREFACE.

THESE important and interesting Letters on "Modern Agriculture" are addressed by Baron Liebig, not to agriculturists alone, but to every one who takes an interest in the welfare of his country.

The wants of an increasing population, and the danger of a possible stoppage, at any moment, of supplies drawn from foreign sources, make all feel a deep interest in the "discovery of the means of producing more bread and meat on a given surface." Landed proprietors, practical agriculturists, and men of science, have all of late years devoted their united energies to solve this important problem. From the efforts of so many anxious labourers, as might be expected, a corresponding harvest of practical results has been obtained. The author, who has for years occupied himself with the elucidation of the laws of the nutrition of plants, passes in review, in these

Letters, the mass of practical facts thus acquired, and by the light of science endeavours to give them their true import, and to deduce from them fundamental laws of general application in agriculture.

It is not long since the humus theory occupied every work on agriculture, and the fertility of our fields was described as entirely dependent on the presence of this supposed valuable substance. The real nature of humus is, however, now understood, as well as the conditions under which alone it can prove valuable in the nutrition of plants.

It is also now well known, that plants cannot grow and attain complete development, without the simultaneous action of the atmospheric food and certain mineral elements, which are absolutely indispensable to their existence. The author has in these Letters shown, that no single element of these indispensable mineral matters possesses superiority over another, but that they are all of equal value to the life of a plant. Hence, if one of them be absent in the soil, a fully developed plant cannot be produced by the others, until the deficient element be supplied. But from the importance of this deficient element in a given case, we are not entitled to infer its equal efficiency in other cases, where the same conditions may not exist;—and yet, this fallacy lies at the root of many of the practical operations of agriculture.

The author points out the nature of this fallacy, and in the discussion of this subject, brings forward new and important facts connected with the nutrition of plants, and with the mode of action of some special manures. The mineral food of plants is shown by him to exist in the soil in two different states; in the one, it is immediately available; in the other, it is not yet brought by decomposition into a condition for absorption by the roots. In every case the produce of a field and the duration of its fertility bear a fixed relation to the sum of the available food in the soil. Hence, if by mechanical or chemical means applied to the soil, we render the absorption of this food by plants more rapid, we thereby increase the amount of produce in a given time, and thus more quickly exhaust the stock. At the end of this given time the field will, for agricultural purposes, be unproductive, if the mineral matters removed by the crops be not restored.

The author directs attention to the fact, that this fundamental principle has been lost sight of in some of the systems of modern high farming, which have been based on the assumption that the available mineral food of plants in arable soils is inexhaustible. He urgently points out that in stimulating the productiveness of our fields by a system of high farming, without at the same time restoring all the mineral matter removed, the present occupiers of the land may rejoice in their abundant crops, but the inevitable result of this system will be the ultimate exhaustion of the soil.

The editor has endeavoured in this translation to convey to the reader as faithful a transcript as possible of Baron Liebig's views; and accuracy has been further insured by the revision of the proofs by the author. In conclusion, the editor begs to acknowledge the kind assistance of his friend Dr. Hofmann, from whom he has received many valuable suggestions whilst the sheets were passing through the press.

JOHN BLYTH.

QUEEN'S COLLEGE, CORK,
April 2, 1859.

PREFACE.

The state of matters to which the contents of these Letters refer, exists in reality in Germany alone; and I should be taking an erroneous view of the actual position of British agriculturists, were I to attribute to them the leading views entertained by German and perhaps French agriculturists. These letters must therefore be regarded as a mirror in which the scientific principles already established, and certain erroneous doctrines prevailing in practice are reflected side by side; and each individual must be left to draw his own conclusions, on comparing his own acts with the standard thus furnished him.

Upon the whole, English agriculture, as a rule, is based on the same spoliation system which exists elsewhere; for though some certainly pursue a rational system, there are but too many who act otherwise.

The remarks which I have made on writers on agriculture and on agricultural training schools, must be received, in like manner, with the same limitation. I am too little acquainted with the English agricultural institutions to pass judgment upon them, and my strictures can only be regarded as applying to those of Germany. With respect to the English agricultural chemists, I also readily acknowledge that Thos. Way, Professor Hodges, and others, have by their researches rendered the greatest service to agriculture.

I cannot, however, concur in opinion with those who would base all progress in agriculture upon elementary analysis and on other useless chemical operations; nor with those who forget that such progress results only from the investigation of scientific laws, and from a correct comprehension of the facts observed,—things that cannot, like products in a manufactory, be procured wholesale by a mere outlay of capital and by a course of experiments.

The great progress made in agriculture, since the end of last century, has been essentially confined to improvements in the practical part, by which I here mean to designate the technical operations of farming; but these improvements have paved the way for the new and higher development of the present day. It is in the nature of things, that in all technical pursuits, and more especially in agriculture, the perfecting of the practice should precede the effective application of scientific principles. So long as the man engaged in a technical pursuit finds that there is still advantage to be derived from improvements in the management of his business, he will not trouble himself with other matters. But by improvements in the practice, or in the management of his business, everything desirable is not attained; the practical operations in themselves give him no insight into his own acts, nor a reliable standard for the value of his observations and experience: at last he will not permit himself to be swayed by the customary mode of proceeding. It is now that he turns to science to satisfy his requirements.

As generally happens in the period of transition into a new state of things, a conflict has of late years been carried on between practice and science; the former was unable to deal properly with the unwonted resources placed at its disposal by the latter; and it is easy to account for the cause of this conflict.

If, in fact, a person of the educated classes, who is not an agriculturist, were to peruse the agricultural works and journals that have appeared of late years, he would find that the preponderating majority of agricultural writers are quite agreed on this one point, that the views which I have put forward on agriculture, have no practical value, and must be looked upon as in part refuted. They maintain that experience, which is older than science, has long since taught the practical man what is needful for him; that the result proves his system of cultivation to be the best suited to existing circumstances; and that his abundant and increasing crops are irrefragable proofs of the soundness of the views which guide his practice.

These expressions and opinions are not generally applicable and valid; they are not, however, groundless. The agricultural literature in which these views are put forward, exists in reality only for the class of thriving agriculturists who are in a position to buy and possess agricultural manuals and journals; and it is evident, that the literature will reflect the requirements, the wishes, and the practice of these agriculturists to whom it owes its existence. It is not in the nature of things that it should be otherwise. As a rule, an agriculturist of this class is a producer of flesh and corn, and is generally possessed of a good property and plenty of capital; his fields comprise meadows and arable land; he keeps a large stock of cattle, produces plenty of farm-yard manure, and is not sparing in its use. If he happens to be short of manure, he has, at all events, money to buy guano, Chili-saltpetre, bone, earth, and rape-dust. He knows the value of farm-yard manure and of the supplementary manures just named, and how to use them to the best advantage. His steward attends to the rotation of crops which has been permanently fixed upon, and to the application of manure at the proper season,—things which do not require the teachings of science; he has to be guided, he tells you, by other circumstances which give him quite trouble enough.

The wealthy landed proprietor is an educated man who has certain intellectual wants. Agricultural literature satisfies these. The writer on agriculture endeavours to prove, by theoretical reasoning, the excellence of empirical practice; he defends the views of the practical man, and strives to invest them with the authority of science. Even if the explanations are at times in complete opposition to undoubted truths, they have at all events this much in their favour, viz., that the agriculturist believes them to be in accordance with his own experience; and, indeed, the object of the writer does not extend beyond securing the satisfaction of the practical man, by showing what is termed the agreement of the practice of agriculture with the theory. Thus, for instance, in the production of corn and flesh, the alkalies in the farm-yard manure remain in the field, and in the progress of cultivation their quantity rather increases than diminishes; a restoration of these alkalies is therefore not required, and would often be superfluous. This circumstance, which arises from the kind of crop grown, the writer explains to the practical man to be the result of the nature of his soil; he informs him that there is no necessity to restore the alkalies removed, because his soil contains an *inexhaustible* quantity of them. It is true that this statement is directly opposed to all that Chemistry teaches; but then it is a matter of indifference whether or not the soil is inexhaustible, if the main point be made out, viz., that there is no compensation of these matters required from without by purchase, &c.

The writer on agriculture further informs the practical man, why guano and other manures used in aid of farm-yard manure are so beneficial. It is clear, he says, that all these matters contain in the nitrogen a constituent common to all of them; and as the employment of each is attended by a similar result, viz., by a corresponding increase in the amount of produce, it is obvious that the effect must be attributed to one and the same cause in all. The practical man is told that in the corn and flesh produced on his land he removes nitrogen; that the exhaustion of the soil is the consequence of this removal; and that, of course, by replacing this nitrogen the productiveness of his fields is restored. To question the fact of the restoration of fertility to land by guano, bone-dust, or rape-dust, would be an act of great folly, for this fact is borne out by the experience of the practical man; the latter, therefore, fully accepts the explanation offered, although there be in it only the merest semblance of truth. He is quite satisfied with the belief that his system of cultivation has been shown to rest on a rational and scientific basis; which, in reality, is not the case.

Practical questions, such as the following: Why the after-effects of the above-mentioned manures are not uniform with those of farm-yard manure, but differ so much from them: or why clover no longer grows on many fields; or why peas, again, yield good crops on the same field only after long intervals: such questions as these, of course, do not engage the attention of the agricultural writer. He speaks of such matters as if ordained by Nature; which cannot be altered; and for which the agriculturist must therefore make due allowance in his system of husbandry. But let the practical man only succeed—which, however, is not likely to be the case—in solving these questions, or in overcoming a difficulty which may have been placed in his way by the writer himself, and the latter will at once proceed with right good will to prove to him by a series of chemical analyses the intimate relation between theory and practice.

These precepts of agricultural writers do no harm to the agriculturists for whom they are intended. These individuals maintain their fields in a permanent state of fertility, by means of farm-yard manure, or by the purchase of guano and other manuring agents; their simple system of cultivation affords no room for exhaustion of the soil. Whatever constituents they remove from the land in the form of corn and flesh, they replace completely, and even in excess.

Although scientific doctrines play a very subordinate part in the system of cultivation pursued by these fortunate landed proprietors, inasmuch as their entire knowledge consists in a few recipes which might be written upon a card; yet it is for them that the most esteemed agricultural hand-books and manuals, and the greater number of the articles in agricultural journals are written; it is for them that books on soils and manures are published, and enriched with stores of scientific learning from the domains of chemistry, physics, botany, and geognosy; it is for their benefit that so many chemical analyses of corn and straw, hay and turnips, are made. They do not, indeed, read or understand all that is written, because, in fact, there is no intelligible meaning in it; and they are quite aware that these rows of figures do not advance their business one hair's-breadth; still they are delighted with all this parade of learning, on account of the seeming deep scientific basis assigned thereby to agriculture, which they follow with so much ardour and profit.

After the wealthy landed proprietors comes a second class of agriculturists, who possess land, but less capital than the former. They obtain good crops by the simple cultivation of their fields with farm-yard manure; they purchase but a small quantity of guano, or other manuring agents; and trusting to the theory maintained by writers on agriculture, that their fields are inexhaustible in mineral matters,—which is intended to apply to a different system of cultivation from theirs,—they believe that there are no limits to the fertility of their land. As they have as yet observed no failure in the conditions of its fertility, they are of opinion that it will be time enough to devise means to meet the necessity when it occurs.

These men also read the agricultural journals, and are quite satisfied in their own mind that the principles of science are not suited to their system of husbandry. They re-echo the opinions of the men of the first class, and are warm supporters of the precepts of the writers on agriculture, although the system of cultivation derived from these teachers brings their fields every year nearer that ruin to which they must inevitably come by following such a system.

The resistance which science has met with on the part of practical men belonging to this class, is partly due to ignorance of its true principles, partly to a wrong conception and interpretation of the same.

If I have criticised the false views and opposition of these men, in purely chemical questions regarding the soil, manures, and the nutrition of plants, with a severity inspired by sincere conviction, it must not be overlooked that they were the aggressors in the conflict. An attack of their views on my part would have been inexcusable; for, with that simplicity which characterises those who presume to judge of things they do not understand, they have candidly avowed that chemistry and the natural sciences are branches of knowledge unknown to them. They are all, without exception, men deserving the esteem which they enjoy in their social relations, and whose feelings as individuals I could not have the most distant intention of wounding; but when they step forward as supporters and propagators of precepts, which have nothing to recommend them beyond the fact that people have for half a century pursued a system of cultivation in conformity with them; which are devoid of all rational basis, and are quite beneath the present position of chemistry and the natural sciences,—precepts which must in process of time dry up the sources of prosperity of the agricultural population,—I should hold it to be a crime against the public interest were I to be restrained by any consideration for individuals, or the position they may occupy, from laying bare the weakness and flimsiness of their arguments, and from exposing their total ignorance of the first principles of chemistry and the natural sciences.

From want of a proper insight into their own pursuit, these men are in their blindness the worst enemies of science, the objects of which they do not comprehend.

The scientific questions connected with agriculture are, in their consequences, of too great importance for any one to enter upon their discussion, before he has seriously considered whether he really understands the subject.

One of the most important objects of the practical man is to discover active manures, by the use of which barren fields may be made productive, and the produce of fertile fields be doubled; but they will never be found, or only accidentally, by seeking them blindfold in an empirical manner. The practical man does not know that for years the study of small and apparently insignificant things must be pursued, before the mind is prepared to grasp questions of importance.

The method followed by science in seeking out active manures is very different, much more toilsome, but more certain. It is rendered doubly difficult from the fact, that the man of science who adopts it has not only to combat the erroneous notions prevailing in the domain of practice, but also the errors of his own science, which have their influence over him, and may cause him at times to make a false step; but he knows that the path leading to light is thorny and dark, and the perception of an error is in itself a victory.

The prevailing agricultural literature has nothing in the shape of aid to offer to the small landed proprietor or farmer; or to him who possesses little or no capital, no good arable land, no meadow, an insufficient stock of cattle, and, accordingly, little or no farm-yard manure; and those who cultivate commercial plants, such as tobacco, hops, flax, hemp, or the vine, find in it no information, no insight into the nature of their pursuit, but only insufficient rules, suited to particular localities.

Science should, however, be the common property of all; it should bestow aid on all who require and seek it, and should increase the intellectual store of rich and poor who are sincerely striving after truth.

From the preceding remarks may be gathered the reasons which have induced me to publish these letters on Modern Agriculture. I am desirous to make the educated men of the nation acquainted with the principles which have been established by chemistry in connection with the nutrition of plants, the conditions of the fertility of soils, and the causes of their exhaustion. Should I be fortunate enough to impress upon a wider circle the conviction of the value of these principles, and of their extreme importance in a national and economic point of view, I shall look upon one of the tasks of my life as accomplished. With the aid of the educated men to whom I address myself, success is, in my opinion, certain; but without their assistance it appears to me to be impossible.

As regards those agriculturists who oppose the teaching of science from ignorance of its objects, I hold it of the greatest importance to be unwearied in our efforts in directing their attention to the facts upon which scientific principles rest; for if we can but succeed in inducing them to reflect on the proofs of these principles, they may be considered as converts to the doctrines of science.

The laws revealed by the study of the natural sciences will determine the future intellectual and material progress of countries and nations; every individual is personally interested in the questions connected with their application.

In conclusion, I have to state that I have been indebted for a number of facts in Letters VI. and VII. to an excellent article in "Chambers's Information for the People," written, as I have since been informed, by R. Russell, Esq., Kilwhiss.

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ERRATA.

Page 68, line 15th from the top, *for* "nitrate of soda," *read* "nitrate of lime."

Page 68, line 19th from the top, *for* "nitrate of soda," *read* "nitrates."

LETTERS

ON

THEORETICAL AND PRACTICAL AGRICULTURE.

LETTER I.

The conflict between Science and Practical Agriculture—The foundation of Agriculture is experience—Progress founded on experience has its limits —The connection of Agriculture with Chemistry and the subsequent reaction—Progress in Agriculture must be based on the Inductive Method —False teachers of Agricultural Science—Practice based on the blind experience of others leads to error—The rejection of scientific teaching by practical men due to their ignorance of the real object of Science—The solution by mere practical men of questions proposed by Agricultural Societies cannot advance Agriculture—The rejection of all scientific instruction by practical men only leads to self-deception.

THE present conflict between practical agriculture and scientific Chemistry, carried on by one party with some animosity and passion, perhaps to the ultimate advantage of the question at issue, might justly claim the attention of enlightened statesmen; for it concerns the weightiest material interests and the fundamental prosperity of the state. The most urgent problem which the present day has to solve, is the discovery of the means of producing more bread and meat on a given surface, to supply the wants of a continually increasing population. The most important social questions are bound up in this problem, which science is expected to solve.

Science has in her own way made the necessary preparations for its solution, but her way does not please practical men. From them she has met with no support, but with opposition in almost every thing she has done.

For the new building, which is to give room and shelter to all who will enter, science has levelled the ground; she has drained it, and driven piles into the swamp, to insure a firm foundation; she has indicated the best stone for use, and pointed out the fact that it is not found in all places, though the mortar may be had everywhere in abundance; she has, finally, given the plan of the house; but not one mason or carpenter, through whose assistance alone the house can be erected, has raised a hand to help her. Experience, they say, has been for centuries their guide, and must continue to be so for the future. In their eyes no views are admissible or possible, which contradict their views based on this experience. What has been regarded from time immemorial as true, must be true. The new plan is opposed to theirs, which is the best; neither the draining of the swampy ground, nor the driving of the piles, nor even the stones which are to be found everywhere, are of any consequence; only the mortar is wanting, on which every thing depends.

Agriculture, like every technical pursuit, is based on experience, that is, on the perception by the senses of facts and phenomena; and it has been enabled by experimental art to reach a certain stage of development. Simple observation shows a certain connection between the condition of the soil and its fertility. Thus, a certain porosity and dark colour bespeak frequently a heavy wheat crop. But as all soils do not possess porosity and blackness, experimental art seeks out the *means* of communicating these properties. It endeavours to produce, for a given object, a passing or a permanent connection between two facts; it seeks to win from the soil a high return by this or that *plant*, *manure*, or other *means*.

Every object attainable by experimental art must be pursued with certain ideas, but it is immaterial whether those ideas be right or wrong. For if we seek an object without knowing the proper way to do so, each path taken by us is, for the time being, the right one. If, then, thousands of persons with the same intention strike out thousands of different courses, it will generally happen that something useful is discovered, although not precisely the object sought. In this way trades have been developed. It is almost incredible what can be done, and has, in fact, been accomplished in this way.

The connection between two objects, such as the soil and manures, is known only through means of a third, viz., the amount of produce. For the practical man, "the matter-of-fact man," there exists no other connecting link.

The exercise of a trade presupposes no intellectual labour; a knowledge of facts, and of their visible and manifest connection with each other, being quite sufficient for the purpose. The baker knows nothing about flour, leaven, or the influence of fermentation and heat; the soap-boiler is ignorant of the nature of the alkaline lye, of fat, and of soap; but both know that by taking certain steps bread or soap is produced. *If the articles look well, they are said to have succeeded.* In like manner, a few years ago, the agriculturist knew nothing about the soil, the atmosphere, or the action of the plough or of manures; things with which he was daily occupied.

The efforts of every tradesman are, as a matter of course, directed to his profits; every improvement in his business has the increase of his income for its object. Hence the baker regards the highest effort of his art to be the production of a white and weighty bread from inferior and bad-coloured flour; and the soap-boiler aims at manufacturing from bad fatty matters a soap with good external aspect. The practical agriculturist, in the same way, endeavours to reap the richest harvest from the poorest soil with the least expenditure of labour and manure. In this petty aim is manifested the paltry principle of the small manufacturer.

The progress of every trade by mere empirical experience, and also that of agriculture, has a limit. Every experimental method comes to an end when the senses are no longer sufficient for the perception of facts; when no new circumstance is presented to the senses for perception; when, in short, everything has been tried, and the facts resulting from such trials have been adopted into the particular art or trade. Further progress can then only be looked for, if hidden facts are sought out, the senses are sharpened for their perception, and the means of investigation are improved. But such a course is not possible without reflection, without the mind also taking its share in the operation.

It is long since agriculture has reached this point of its progress. As, however, in following out their own practical mode, agriculturists had never troubled themselves about the way or the means of discovering hidden facts; it was evident that without the aid of Chemistry,—the science which communicates this knowledge,—they could never attain their end. Chemistry most readily responded to the call. In the very outset the practical agriculturist was informed by the chemist, that his conception of the words *air*, *soil*, *manure*, was indefinite, and ambiguous; that they had a fixed and definite meaning, and that it was only in this strictly defined form that they could be employed in processes of reasoning. Chemistry thus elevated mere practical notions to the rank of *scientific conceptions*.

The newly acquired conception of manure was accepted with enthusiasm by agriculturists, and they set themselves with zeal to work it. It was known that manure was the most important element in increasing a crop. It had been shown that the word "manure" was a collective term; that it consisted of parts, and that its activity depended on its constituents. The practical agriculturist now began to operate with the parts as he had done with the whole manure. But as a part can never replace a whole, so the results, by this mode of proceeding, did not answer his expectations. No progress was made. Enthusiasm began to cool, and reaction commenced.

"It is utterly absurd," says Mr. Pusey (late President of the Agricultural Society of England), "to put any value on the doubtful precepts of Chemistry. It has done nothing for agriculture, with the exception of giving a receipt for increasing the efficacy of bones by the action of sulphuric acid, and of proposing to employ flax-water instead of liquid manure. We must keep to practice, for it alone is worthy of confidence." Every practical man in England, Germany, and France, quite agreed in this opinion. Chemistry had done them no good; it had not increased their crops, nor augmented their incomes.

As if freed from a frightful night-mare, blind empirical practice again raised her head, and made new and extraordinary efforts to refute the conclusions drawn from scientific principles. The continued efforts of ten years have, however, shown that practice has only been moving in a circle, like a horse in a mill. More horses have been yoked; but as the beam was not lengthened, the circle has remained the same, only somewhat more trodden than formerly.

A new movement now occurred in agriculture. Science pointed out that the very facts destined to refute her doctrines, exhibited the fullest proofs of their soundness. Agriculturists had themselves to blame for their want of success, by not taking the right path and by mistaking the nature and essence of science. It is not at all the province of science to seek out the means of increasing produce or augmenting incomes. She inquires not after what is profitable; this belongs to experimental art, with which she has been confounded. The business of science is to seek for causes, and like a light, to illuminate the surrounding darkness. Science confers *power*, not *money*; and power is the source of *riches* and of *poverty*,—of riches when it *produces*, and of poverty when it *destroys*; it is expended by *use*, and renewed by *supply*.

If agriculture is to arrive at results which are to be lasting, she must decide upon entering on that path which science has recognised to be the only trustworthy one to lead to a knowledge of hidden objects and their relations. This could be done without renouncing one of the facts acquired by experience. There is no lack of these, but agriculturists are at fault in their mode of comprehending them. They must, in the first place, desist from drawing hasty conclusions for special purposes from these facts, and only occupy themselves with investigating the proximate conditions of all the facts connected with the life and development of plants, the production of which is their object. From the favourable action of the constituent of a manure in one case, they must not at once infer its equally favourable action in another, in order to derive immediate profit from it; but they ought, in the first place, to inquire into the reason of its good effects in the special case.

Such investigations are in an agricultural point of view greatly facilitated by all the conditions of the incidents, or effects, or their proximate causes, being clearly perceptible by the senses, and palpably manifest if we know the proper way to proceed.

The favourable action of a manure A is always dependent on certain physical conditions of the soil, and on the presence of a second substance B, of a third C, of a fourth D, and so on. After investigating these different points, our conclusion must then be submitted to proof, which must show whether all the conditions have been considered together, and none overlooked. We must endeavour to produce the same effect in another soil, by the combination of all the conditions found. Should the result correspond with our expectations, and be equally favourable as in the first instance, we have made an extraordinary step in advance; for from this special case we can now in all similar cases predict the like or unlike effect of the manure A. The effects will be like, in every instance in which we know that we have present the same conditions united in the same manner; and unlike, when one of these is known to be wanting.

The presence and united action of all the conditions of the effect observed, is designated by the term, a *special law;* because it refers to a special case, to a certain plant for instance. If this law holds good for superphosphate of lime and "turnips," it does not follow that it is equally true for "wheat." But a similar special law can be established for each manure, each plant; and from these again general laws can be deduced, which express the conditions of the growth and development of *all varieties of cereals, all species of turnip and tuberous* plants, &c. These connected general laws now receive the name of *theory*.

It must be evident, even to the most limited understanding, that there is nothing hypothetical in this proceeding. It differs from blind experimental art, only in being the result of thought and reflection. As the train of thoughts, on which the experiments are based, is carried out in a precise and fixed direction, this mode of proceeding has received the name of the *inductive method.*

The world has been metamorphosed by the introduction of this method, which was unknown to antiquity. It is to this method that the present day is indebted for its peculiar characters. The Greeks and Romans possessed metaphysics and the fine arts as we do; but the natural sciences, the offsprings of the inductive method, were unknown to them. To this method we owe the millions of willing and industrious slaves, whose labour costs no tears or groans. It has bestowed on Germany alone what is equivalent to from 700,000 to 800,000 horses, which, with untiring energy and with the speed of the wind, bring from the most distant lands their various products to satisfy the wants of man; and they need no hay, no corn to feed them. The fruitful land necessary to produce the food for this number of horses of flesh and blood, remains for the use of five to six millions of men, who can be maintained on its surface.

Conclusions deduced from this method of investigation, are evidently but the intellectual expressions for experiments and facts. The practical man who adopts this method of solving all useful questions, need entertain no dread of acquiring the reputation of a theorist, which he considers to be of a rather doubtful nature. He may rest assured that by no other means can he solve a single problem. He must first seek after the "why," and the "wherefore" will follow as a matter of course.

It would be unjust to conceal the fact that, for more than half a century, agriculturists have directed all their efforts to gain an insight into the processes of husbandry. They have endeavoured to connect all its phenomena together by some intelligible bond, and to ascertain the relation and dependence of its scattered facts.

Agriculture could not remain unaffected by the extraordinary progress of other trades depending on the action of natural forces. The natural sciences were even recognised to be the source of this progress. Wise and intelligent princes erected schools and institutions, for the express purpose of teaching the doctrines and truths of the natural sciences in connection with the practice of agriculture, of investigating the best modes of cultivation, and of widely spreading the knowledge of them.

Agriculturists felt the necessity of accounting for their acts; and the knowledge that they were doing the right thing in the right way, appeared to all indispensable to progress.

If we open a recent handbook of practical agriculture, we at once see the zeal with which this task has been performed. The effect of soils, manures, irrigation, drainage, and the action of each fertilising agent on individual classes of plants, are all brought into harmony and explained in the most beautiful manner. Everything seems in such works to have been investigated and ascertained; no process is involved in obscurity; and a certain feeling of pride seems to fill the breast of the teachers who have done so much to elevate agriculture to the rank of a science.

*But this is all sham, without a single law or a single truth.** "If there is a class of mind in the world

* The Chronicle of a Clay Farm, by Talpa.—*Agricultural Gazette.*

which has a native antipathy to improvement, there is another and much more really mischievous, which seems ever destined to caricature it. . . . These are the blundering enthusiasts who dog the path of progressive truth, like distorting shadows, throwing her calm profile against walls, trees, and passing objects, in every variety of burlesque and ridiculous outline; . . . exaggerating every account like street newsvendors; dressed in the livery of science like a monkey in regimentals, and understanding and appreciating the language they talk at second-hand, as much as the organ-grinder does the opera tune that his winch works threadbare.

"Agriculture has had enough of this and something to spare. Counterfeits of every sort and shape have crowded at the heels of every improvement, every invention, every good suggestion, every new manure; till art and science are well nigh ashamed of their own names, and are fain to wear smock-frocks for an incognito. The plague that has reached its height in the present decade, was beginning its infective process in the last of our nineteenth century."

Agriculturists knew not that the explanation of the most trifling incident or process, or the discovery of the almost self-evident cause of an effect, costs much pains and circumspection; that in chemistry, for example, the simplest explanation of a single individual fact has been attained, only by persevering labour. They thought that to *will*, was to obtain possession; and they hence gave themselves up to the direction of those caricaturists of science who promised them success without any efforts on their part. They were well pleased with their sham scientific mode of proceeding, with which they were at home, and which cost them but little trouble. The language alone was new, but technical terms were soon learned. Each individual considered himself as fully qualified to institute chemico-agricultural experiments; and these were undertaken even by men who knew no more about chemistry than the student who considers that the distillation of a fluid is to be attained by simply placing it in the sun, or the other who asked the chemical assistant in a laboratory for a grater to pulverise a mineral.

Such men arrived at explanations in the simplest manner possible. If between two facts there existed a certain and unmistakeable connection,—such as, for example, between *irrigation* and the *increase* of grass on a meadow,—these pseudo-scientific experimenters drew on their imaginations for the explanation of this connection.

The causes of the effect produced were unknown. There was, however, an effect visible, and it must have a cause. The expounder began first by mystifying with a chemical hocus-pocus of analysis, the good-natured agriculturist thirsting after knowledge; and when he had sufficiently confused the sound common sense of the latter by unmeaning numbers and calculations, he quietly palmed off on him his explanation which he had ready prepared.

The connection between two facts was not, however, always so palpable, as between irrigation and production of grass; but our agricultural expounders were never at a loss. If they wished to show, for example, the connection existing between the *exhaustion* of the soil and the cultivation of *cereals*, they required only to call to their aid certain speculative views derived from experience. For such occasions they had always ready chiefly two famous theories, viz., the "bone earth" and the "nitrogen" theories. The latter has attained great celebrity in England, and in Germany, too, it has found ardent supporters.

There can be only one straight line between two points; but billions of curved lines may connect them. Thousands of hypotheses may, in like manner, be propounded to explain the connection of two facts; but there can be only one right theory. Every one will therefore understand that agriculture, by following the method described above, could never arrive at the right way of explaining her various facts. The popularity of this mode of proceeding arose from the circumstance, that knowledge was not required to practise it. Every agriculturist, in his own estimation, possessed the necessary qualifications for the purpose. He knew the facts, and his own experience was quite sufficient to connect them. But as the individual experience of each necessarily varied in many respects, it followed that each had his own peculiar theory for his proceedings and his mode of viewing things.

In reality these theories were but little regarded. The practical man kept to what had been tried, and acted upon it. If his neighbour made a successful trial, he imitated his example. This was his mode of making progress; he knew no other.

The practical agricultural system of instruction was a mere collection of different receipts suitable to known cases; it was an olla podrida of facts, with theory as a kind of sauce to it.

The agriculturist commencing his career became a practical man, and acquired reputation and honour somewhat like the so-called "green" Doctor of Offenbach on the Maine, who will perhaps still be recollected by the older inhabitants of this town. He was a Jewish physician of renown who was called in to all dangerous cases of illness in Frankfort, Hanau, and the neighbourhood; and his practice was not without success. Nature had given him a quick eye and fine powers of observation. His knowledge was obtained in an hospital in which he acted as sick attendant. He used to accompany the physician through the sick wards, looked at the tongues and urine of the patients after him, felt their pulse, and superintended the orders about their diet. He copied the prescriptions regularly; marked them with a red cross when the patient recovered, and with a black one when he died.

His sheets grew by degrees to the size of a book, and when nothing new presented itself to be added to it, he began in the first instance to practise on a small scale, and then started on the full career of physician. He was skilled in diagnosis, and had his prescriptions for the various cases. Those with the red crosses came first; and, if unsuccessful, then followed the black. In this way he acquired his own experience. He was very orthodox, and on the Sabbath day would write no prescription, but would then dictate them in the apothecary's shop to the assistant. He commenced with "*Rrrrr*" (this meant Recipe); "*Tartemet*, two grains" (*i. e.* Tartari emetici grana duo); *Syralth* (*i. e.* syrupus altheæ). He could not read his own prescriptions, but his fame as a practical physician was so established, that the regularly educated physicians in Offenbach could not succeed in putting an end to his career, on the ground of his never having received a medical education.

Agricultural practice is acquired in the present day exactly in the same way as the medical skill of the Offenbach doctor. The young agriculturists become sick attendants in an agricultural hospital; they copy the prescriptions, and when they depart for the purpose of beginning practice, the kindly directors send them on their way, with the substance of two years' earnest devotion to all the auxiliary sciences summed up in an axiom, "Dung, Guano, and Bone-earth, you must not forget, gentlemen, are and remain the soul of agriculture."* They knew this very well. They had been taught that no trust was to be put in chemistry or physics; that food and drink keep body and soul together; and that beer, bread, and meat, are the soul of the handicraftsman.

Under such circumstances, it cannot excite astonishment, that for more than sixteen years true science found no soil in agriculture for its development. The most exact inductive conclusions were only regarded as hypotheses. It has ever been the case that when error sat enthroned, truth, like a felon, was kept bound in chains. What arrogance in science to regard practical men like us as blind men, and to attempt to make us see. How can men who know not whether potatoes should be planted in March or April, presume to teach us the properties which land suitable for potatoes ought to possess,—or what is the nature of *fallow?* Such scientific explanations are not based on experience; we can ourselves give much better. Whoever should attempt to depose farmyard manure from its exalted position, deserves to be burnt alive!

Agriculturists had not yet acquired the faculty of distinguishing between mere opinions and correct facts. Every fact was acceptable; every opinion was received by them. *If science doubted the truth of one of their explanations, they imagined that she was disputing their facts.* If she asserted that a great progress would be made by substituting for stable manure its

* See G. Walz. Beleuchtung. p. 128.

active constituents, they believed that in doing so she denied the efficacy of the former.

About misunderstandings of this kind disputes then arose. The practical man did not yet understand the deductions of science. His dispute was with the bugbear of his own false conceptions, not with science. He did not know that science also has a moral of her own, the foundation of which lies in the precepts of the school and their practice in education.

As a means of mental training, the study of the natural sciences was quite unknown to the practical man; and hence the difficulty which existed between him and the scientific man of mutually understanding each other. Had the former turned his attention even in a slight degree to these sciences, he would of himself have acquired all the information which it now costs so much trouble to make intelligible to him.

In physics and chemistry, disputes of this nature occur no longer, though the time is not long past since both were at that point of development which agriculture has still to pass.

A glance at a chemical or physical journal must fill the mind of an agriculturist with astonishment at the mass of problems and their solutions which it contains, and at the immense labour which has been readily and without reward bestowed upon the whole. Each day brings its own progress without strife; for each cultivator of these sciences knows what constitutes a fact, conclusion, rule, law, opinion, and explanation. There are specific tests for all these which everyone uses, before he puts each to the test of its own peculiar touchstone, before he circulates the fruits of his labour. Each assiduously seeks to bring to light hidden facts, which are immediately submitted to proof by others, and receive their proper place when they are found to be genuine. One individual possesses the talent for seizing the points of resemblance between two facts; another has a keen eye for their differences; in this way they render mutual assistance in the proper elucidation of phenomena. Special pleadings on the part of any one for his own peculiar views, without striking facts to support them, or the attempt to palm off on others any unproved facts, is instantly rebutted by the moral of science. The earnest desire of a mutual understanding is ever paramount.

The most intelligent representatives of agriculture have hitherto erred in not discussing their questions in the way which would have led to the attainment of their object. Great agricultural associations, as well as individuals, have proposed questions, and recommended their solution as absolutely necessary for future progress. The majority of agriculturists have a monomania for propounding such questions, and deceive themselves with the belief that their solution will be attended with sound practical information. Not one of them knows exactly what is wanted, but each is anxious to contribute his suggestions. Such questions propounded by persons who know nothing of the subject, are answered by others who understand it as little. Not one, however, really cares about the answer, for they all clearly see that they would not know what to do with it.

There is a good method of satisfying ourselves of this fact. We have only in our minds to answer these questions with "yes" or "no," or with any negative or positive number we choose, when the answer involves numbers, and we shall at once see that they are thoroughly unpractical, or belong to the same stamp as the prize question of a well-known Academy—"The decomposition of Nitrogen," a problem which now seems to us more difficult, than the solution of charcoal for the purpose of making diamond. The solvers of such questions (and here I speak only of agriculturo-chemical), are hence always persons who do not possess the necessary knowledge to make the most trifling discovery. About fifteen years ago Hlubeck propounded a series of questions, on the solution of which the very existence of agriculture appeared to him to depend. Since then, neither he nor any other person has troubled himself about the matter; and the present state of the development of agriculture is a proof, that none of his questions stood in any relation to it, or exercised any influence upon its progress.

These questions are always tokens of progress. They prove that agriculture has really passed from the state of blind empiricism into the first stage of its scientific development, viz., into that of its infancy, in which curiosity manifests itself by a multitude of questions. In this point of view we may, after all, rejoice that such questions are really put.

Chemistry and physics have likewise passed through the same stages. Academies and learned societies have in their time proposed an incredible number of absurd prize questions and impossible problems, without having thereby exercised any important influence on the furtherance of science. Those who are not well acquainted with the position in which these problems stand to science, would be easily misled into the belief that they have given origin to many truly substantial works. This is, however, an error, for the problems were proposed by those who knew that their solution was already in progress; or the questions came accidentally in the way of men who had been long previously occupied with them.

Prizes, sometimes of a very high value, were attached by the Academies to the solution of their questions; but as our excellent agriculturists regard the answering of their questions as an honour, they may, on that account, calculate the more certainly that nobody will take any notice of them.

At their great meetings, the practical agriculturist communicates his experience, and expresses his views. The final result is always a mutual agreement between those who differ in opinion; and each goes home with the proud consciousness of having convinced the others that he is a man of progress, and has taken his part in it. Principles are left out of the question; effective manures and experiments alone are wanted. Poor soils cannot be fertilised by fundamental truths.

A few years ago a writer expressed in such a meeting a modest doubt as to the duration of the nitrogen theory so strongly maintained in England, but they unanimously passed to the order of the day, as experience had long since decided the question of its value.

One of the worst points in the character of practical men, is their sensibility to opposition. The total want of foundation for their erroneous views is the reason why they regard them with so much affection and tenderness. It makes them blind to their own interest, and deaf to all instruction. They look on every one as an enemy who does not flatter their prejudices, who openly tells them that there yet remains much to be learned, and that the consciousness and confession of our ignorance, and the knowledge of our faults are the first steps towards improvement. I, who in my heart believe myself to be their most candid and sincere friend, must, therefore, at once make up my mind to bear with resignation the whole weight of their contempt, with which pride in their own experience fills them, if I attempt to prove the assertion, that the prevailing system of agriculture for half a century has been one of spoliation; and that, if persisted in, the inevitable result will be, at no distant date, the ruin of their fields, and the impoverishment of their children and posterity.

LETTER II.

Present profit is the leading principle of the prevailing system of Husbandry—This system is one of danger to Agriculture—General view of the Nutrition of Plants—Atmospheric and Mineral Food—The absolute necessity to Plants of all the Constituents of their Mineral Food—Present views of the Nutrition of Plants erroneous—Rain water does not dissolve out the Mineral matters in the Soil—Remarkable absorbent power of Soils for the soluble Mineral Food of Plants, and particularly for Potash, Ammonia, and Phosphoric Acid—This power is limited, and varies with the Soil—Organic matter in the Soil materially modifies this power.

BEFORE proceeding to prove that our present system of agriculture is one of spoliation, I must from the outset remark, that I do not by this mean, that each agriculturist acts contrary to the rules of logic and common sense in tilling his ground in the manner most advantageous to himself. On the contrary, I feel satisfied that, so far as the attainment of *this* point is concerned, our practical agriculturist is very reasonable and logical. He knows, in general, the means of rendering barren grounds fertile, and of obtaining the best crops from fertile fields; and he employs these means with reflection and skill, for they have been known and proved for ages.

A field from which a large crop of corn has been reaped, is again enabled to produce the same crop by *mechanical preparation* and by *manure*. Any peasant, who cannot read or write, knows that such a result will follow the employment of these two means.

It is asserted, that the present system of husbandry yields greater crops, and produces more corn and meat, with more profit, on the same area than formerly. I will not, at present, contest this point, and therefore it is not now my object to attack this *system*, but rather to discuss the question, whether or not it is a *rational one*. If the large crops are a consequence of a mode of management by which the ground must gradually lose the conditions of its fertility, by which it must be impoverished and exhausted, then such a system is *not rational*, though it enrich the individual who obtains these high returns.

I am aware that the majority of agriculturists are fully satisfied that their mode of husbandry will insure a continuance of fertility to their fields. If I can succeed in awaking a doubt in this belief, I shall have gained an important point. The simple perception of their error will suffice to lead to its correction.

I hold it, indeed, to be no longer possible to bestow again upon the soil all those conditions of fertility which have been withdrawn by the existing mode of husbandry; but, by a judicious system of management, so much may be accomplished with the still existing means, as to put in the shade all that has hitherto been done.

To comprehend clearly the existing system of agriculture, we must recall to mind the most general conditions of the life of plants.

Plants contain combustible and incombustible constituents. The latter, which compose the ash left by all parts of plants on combustion, consist in the case of our cultivated plants, essentially of *phosphoric acid, potash, silicic and sulphuric acids, lime, magnesia, iron, chloride of sodium.*

It is now regarded as an undisputed fact, that the constituents of the ash are elements of food, and hence are indispensable to the structure of the different parts of the plant. Its combustible portion is derived from *carbonic acid, water, and ammonia,* which as elements of food are equally indispensable.

By the vital process plants are formed from these materials, when the atmosphere and soil supply them at the same time in suitable quantity, and in the proper proportions. The atmospheric elements do not nourish without the simultaneous action of the elements of the soil; and the latter are equally valueless without the former. The presence of both is always required for the growth of the plant.

It hence follows, as a matter of course, that no single element of the food of plants, named above, possesses superiority over another: they are all of *equal value* to the life of the plant. But to the agriculturist, who must provide a suitable supply of all these substances in his land to accomplish his particular object, they are, on the other hand, of *unequal value.* For should there be a deficiency of one of them, he can calculate on his crop only by supplying that particular one to the soil. The deficient or absent element then acquires a *superior value,* that is, in relation to the other matters (for example, lime in a lime soil), which the soil contains in greater quantity.

All elements of food of plants belong to the mineral kingdom. The *gaseous* elements are taken up by the leaves; the *fixed* by the roots. The first are frequently constituents of the soil, and, as such, reach the interior of plants by the roots as well as by the leaves. From their nature, these gaseous elements are *movable;* the incombustible ingredients are *immovable,* and cannot of themselves leave the spot in which they are found.

An element of food is ineffective if there be absent a single one of the other elements of food which are conditions of its activity.

Corn plants, and those used for fodder, require for their development the same constituents, but in very unequal proportions. The successful growth of a green crop on a field, proves that it has found in the air and in the soil the atmospheric and mineral constituents of its food in the proportions suitable for its nourishment. The failure of a corn crop on the same field, indicates that in the soil there is something wanting which is necessary for its growth. Hence we must in every case of the failure of a cultivated crop, look to the ground for the cause, and not to any want of atmospheric food; for the same source of atmospheric food was available to the corn plant as to the green crop.

But how does the soil act, and in what manner do its constituents take part in vegetation? This question we shall now consider a little more in detail.

The process of nutrition consists in the appropriation of food. A plant grows by increasing in bulk; and its bulk increases by the constituents of its food becoming constituents of its frame. From carbonic acid, for example, sugar is formed; silicic acid becomes a component part of the stem; potash of the sap; phosphoric acid, potash, lime, magnesia of the seed.

In considering the effect of an element of food, we have to distinguish between the *rapidity* and the duration of its action.

In general the result depends on the sum of the active elements available in the soil, in relation to the amount which the plant may altogether absorb, and does absorb, during the period of vegetation. A deficiency diminishes the crop, but an excess does not increase it beyond a certain limit. The excess comes into play in the succeeding period of vegetation. The continuous cultivation of crops is regulated by this excess which remains in the ground after each period of vegetation. If this residue is ten times greater than is necessary for a full crop, then it will suffice for ten full crops during a period of ten years.

The *rapidity* with which a substance, such as a piece of sugar, is dissolved by a fluid, is in proportion to its state of *division*. By pulverization its surface is increased, and consequently the number of points augmented, which, in a *given time*, are brought in contact with the dissolving fluid. In all chemical processes of this kind, the action proceeds from the surface. An element of food in a soil acts by its surface, the portion beneath the surface is inactive, because it cannot be dissolved. Its effect, within a given time, increases with the quantity taken up by the plant during that time. Fifty pounds of bones may in one year produce, according to their state of division, the same effect as one, two, or three hundred pounds coarsely ground. In the latter state it is by no means inefficient; but to act, that is, to become soluble, it requires a longer time. The effect produced by it is smaller, but it continues longer.

To understand correctly the effect of the soil and its constituents on vegetation, we must keep steadily in view the fact, that the elements of food present in it always possess within themselves active powers, but they are not always in a condition to exert this power. They are ready to enter into circulation, like a maiden to dance, but a partner is necessary.

The agriculturist requires eight substances in his soil, if all his plants are to flourish luxuriantly, or his fields to produce the largest crops. Many of these, though not all, are always present in quantity; three require to be added to most fields. These eight substances are like eight links of a chain round a wheel. If one is weak, the chain is soon broken, and the missing link is always the most important, without which the machine cannot be put in motion by the wheel. The strength of the chain depends on the weakest of the links.

We have hitherto believed that plants received their food from a solution, and that the rapidity of its effect was in direct proportion to its solubility. We have supposed the active elements to be carried in solution in rain water and carbonic acid to their roots, and have regarded them in the light of sponges, half in the moist ground and half in the air, continuously absorbing by their roots the water which evaporated from their leaves. Whatever was in solution passed with the water into the roots, and by the process of nutrition was appropriated by the plant. The soil and the plant were both passive in the operation.

Vegetable physiology has taught, that an element of food in the soil, at a distance from the rootlets of plants, is available as nourishment, provided there is water between the rootlets and the food to dissolve the latter. In consequence of the evaporation from the leaves, the rootlets suck up the water, which thus, with the substances dissolved in it, receives a movement onwards towards them. We believed that the water was the carrier of the most remote elements of the soil to the immediate presence of the plant.

If 4000 lbs. of grain and 10,000 lbs. of straw require 100 lbs. of potash and 50 lbs. of phosphoric acid for their development, and if a hectare of ground contain these quantities in a soluble available form, then there will be sufficient for this crop. If the same field contain double, or a hundred times as much, then we should expect two or a hundred crops. This has been the physiological doctrine.

But all this has been a great mistake. We have inferred from the effect of water and carbonic acid on rocks, a similarity of action on soils; *but this conclusion is false.*

There is not to be found in chemistry a more wonderful phenomenon, one which more confounds all human wisdom, than is presented by the soil of a garden or field.

By the simplest experiment, any one may satisfy himself, that rain water filtered through field or garden soil does not dissolve out a trace of *potash, silicic acid, ammonia,* or *phosphoric acid.* The soil does not give up to the water one particle of the food of plants which it contains. The most continuous rain cannot remove from the field, except mechanically, any of the essential constituents of its fertility.

The soil not only retains firmly all the food of plants which is actually in it, but its power to preserve all that may be useful to them, extends much further. If rain or other water, holding in solution *ammonia, potash, phosphoric and silicic acids,* be brought in contact with the soil, these substances disappear almost immediately from the solution; the soil withdraws them from the water. Only such substances are *completely* withdrawn by the soil as are *indispensable* articles of food for plants; all others remain wholly or in part in solution.

If a funnel be filled with soil, and a dilute solution of silicate of potash be poured upon it, there will not be found in the filtered water a trace of *potash*, and only under certain circumstances *silicic acid.*

If freshly precipitated *phosphate of lime*, or *phosphate of magnesia*, be dissolved in water saturated with *carbonic acid*, and filtered in like manner through soil, there will not be found a trace of *phosphoric acid* in the filtered water. A solution of phosphate of lime in dilute *sulphuric acid*, or of *phosphate of magnesia and ammonia* in carbonic acid water, comports itself in the same manner. The phosphoric acid of the phosphate of lime, and the phosphoric acid and ammonia of the magnesia salt remain in the soil.

Charcoal re-acts in a similar manner with many soluble salts; it removes colouring matter and salts from solutions. It is natural to look upon the effect in both cases as proceeding from the same cause. In the case of charcoal, it is a chemical attraction, which proceeds from its surface; but the constituents of the soil take part in its action, and hence it must in many cases be quite different from that of charcoal.

Potash and soda are well known to stand to each other in the closest chemical relation, and even their salts have many properties in common. Chloride of potassium, for example, has the same crystalline form as chloride of sodium; and in taste and solubility they differ but slightly. An unpractised eye can scarcely distinguish them, but the soil can do this in the most perfect manner.

If we add any soil in powder to a dilute solution of chloride of potassium, in a short time there will not be found any potassium in solution. The same quantity of earth does not withdraw from a solution of chloride of sodium, containing an equal amount of chlorine, even the half of the sodium. Consequently, a complete decomposition takes place with the potassium, but only in part with the sodium. Potash is found in all our land plants, but soda forms only an exceptional constituent of their ashes. From sulphate and nitrate of soda, the soil withdraws only a part of the soda, but the whole of the potash from the corresponding potash salts. Experiments, expressly made for this purpose, have shown that 1 litre = 1000 cubic centimetres (= 61 cubic inches Eng.) of garden soil, rich in lime, will take up the potash from 2025 cub. cent. (= 123·6 cub. inches, or 3½ pints) of a solution of silicate of potash, which contains in every 1000 cub. cent. 2·78 grammes (= 43 grs.) of silicic acid, and 1·166 grammes (= 18 grs.) of potash. From these data we can calculate that a field of a hectare (= 2½ acres) in extent, and having a depth of ¼ of a metre (= 10 inches nearly) of soil, of the same kind as that used in the experiments, would withdraw from a similar solution more than 10,000 lbs. of potash, and retain them for the use of plants. A similar experiment, made with a solution of *phosphate of magnesia and ammonia* in carbonic acid water, showed that a 2½ acre field would withdraw 5000 lbs. of this salt from such a solution. A loam (poor in lime) produces the same effect.

These facts give us some conception of the powerful action of soils, and of the strength of their attraction for three of the chief elements of the food of our cultivated plants, which, in consequence of their solubility in pure and carbonic acid water, could not be retained in the soil, did the latter not possess this power of attraction.*

* These experiments are so simple and so easily performed, that they may be exhibited at lectures. In filtering, care must be taken that the fluid does not form canals, which would prevent the complete contact of the solutions with the soil. Very dilute solutions of silicate of potash, chloride of potassium, &c., must therefore be used, in the proportion, for example, of one part of substance to 500 of water. Saturated solutions of the other substances, such as phosphate of lime in carbonic acid, may be employed. Generally, in the first portions of filtrate from the phosphate of lime, not a trace of phosphoric acid can be detected by molybdate of ammonia. A solution of silicate of potash, which re-acts distinctly alkaline with turmeric paper, instantly loses this re-action by simple mixture with soil. This power of absorption in soils for ammonia was observed by Thomson, and for phosphoric acid and some potash salts by Way, so long ago as 1850; but up to that time neither vegetable physiologists, nor scientific agriculturists, had taken notice of the remarkable discoveries of these English chemists, so pregnant with important results to physiology and agriculture.

From *stale urine, liquid manure* diluted with much water, or from a solution of *guano*, soil, when used in sufficient quantity, removes the *whole* of the *ammonia, potash*, and *phosphoric acid* which they contain. Not a trace of these substances can be found in the water which flows from the soil. (Thomson, Huxtable, Way.) *

The power possessed by soils to withdraw ammonia, potash, phosphoric and silicic acid, from solution, is limited. Each soil is endowed with its own peculiar capacity in this respect. When brought in contact

* I cannot here omit a circumstance communicated to me a few years ago by Dr. Marquart, of Bonn, and which illustrates, in a remarkable enough manner, the power of absorption of clays for ammonia.

A manufacturer on the Rhine conceived the idea of extracting, by means of ammonia, the oxide of copper, which was found as malachite and azure-spar dispersed through shale. The experiment had succeeded with him on a small scale. At a considerable expense, he constructed a large extraction apparatus, consisting of two boilers connected by a very wide tube. The fluid ammonia was placed in one boiler; the tube was filled with the shale; and the second boiler served as condenser. By this arrangement it was intended that the ammonia and vapour of water should be condensed in the tube, and, after dissolving the oxide of copper, pass over into the second boiler. The tube was then to be filled with fresh shale, the ammonia to be driven by heat from the solution in the second boiler, and made again to extract the copper from the fresh shale. As the whole apparatus was hermetically closed, it was hoped that the same quantity of ammonia would serve without loss to extract large quantities of shale. The boilers were employed alternately as condensers. The first trial was so far successful, that a solution of oxide of copper really collected in one of the boilers. But on passing the ammonia through a second portion of shale, it disappeared in a manner most incomprehensible to the manufacturer. The process had in consequence to be abandoned. The disappearance of the ammonia in this operation was undoubtedly due to the absorbent power of the clay of the shale. This fact may be taken as a proof of the powerful attraction existing between these two substances, which apparently could not be overcome even by the influence of a high temperature.

with these different solutions, the soil becomes saturated with the dissolved matter, and the excess of soluble substance then remains in solution, and can be detected by the ordinary re-agents. A sandy soil absorbs less than the same volume of a marly soil; and the latter less than a clay soil. The variations in the quantity of matter absorbed are as great as the differences existing among the soils. We know that no two are alike; and it is not improbable that certain peculiarities in cultivation stand in a certain relation to the unequal power of the different soils for absorbing one of the above substances. It is not impossible, that, by a closer study of this relation, we may arrive at quite new and unexpected means of judging of the agricultural value or fertility of our fields.

The action of a soil, rich in organic matter, on the solutions above mentioned, is worthy of remark. A clay or lime soil, poor in organic matter, withdraws all the potash and silicic acid from a solution of silicate of potash; whereas one rich in so-called humus extracts the potash, but *leaves the silicic acid in solution.* This comportment involuntarily recalls the action of decaying vegetable remains in the soil on the growth of plants, which, like reeds and horse-tails, require a large quantity of silicic acid. These plants abound in so-called sour moor and meadow lands; but disappear from them on the application of lime, and give place to others better fitted for fodder.

Experiment shows, that the same garden and forest soil, rich in humus, which withdraws no silicic acid from a solution of silicate of potash, immediately acquires the power to do so, if it be mixed with a little slaked lime before the silicate is added to it. Both constituents, potash and silicic acid, are then retained by the soil.

LETTER III.

Our cultivated plants do not receive their food from Solution—Roots of plants derive their Nourishment only from those portions of Soil absolutely in contact with them—This view supported by the composition of River, Well, and Drainage water—The Roots of plants must themselves exert some peculiar action in Nutrition—The Life of land-plants endangered by food when in Solution—In Water-plants the laws for the absorption of Food must differ from those of Land-plants—The Ash of duck-weed shows that plants have a Power of selecting their Food—Reason why mud from stagnant pools is a good Manure—Remarkable power for absorbing Moisture possessed by Soils—By absorption and evaporation of Moisture, the Soil is warmed or cooled—Great importance of this fact to Vegetation—The two Sources from which Moisture is absorbed by the Soil—Natural Law deduced from the above facts.

THERE can be no doubt, from the action just described of soil on potash, ammonia, and phosphoric acid, that the majority of our cultivated plants cannot receive out of a solution from the soil their essential mineral constituents. For if, after filtering a solution of potash or ammonia through a layer of soil of no greater thickness than usually occurs in a field, these substances are so completely withdrawn from the powerful acids with which they are combined, as well as from the watery solution, that chemical analysis can scarcely detect a trace of them in the filtrate, it is not probable that rain-water alone, or even by the aid of a small per-centage of carbonic acid, should possess the power of extracting them from the soil, and forming a solution which should not again be decomposed by passing through the ground. The same fact holds good for phosphoric acid and its salts. Carbonic acid water will everywhere dissolve phosphate of lime when it comes in contact with it; and the consequence of this solution can only be its distribution through the soil. But such a solution could not pass from the spot in which it is formed without being deprived of all the dissolved salt by such portions of the soil as are not already saturated with it.

These substances are present in the soil in a condition somewhat like colouring matter in charcoal, or iodine in starch, fit for absorption by the rootlets of plants, but not by themselves soluble in rain water, or removable by this solvent until the soil is saturated with them.

It is more than probable that it is assigned to the majority of our cultivated plants to receive their nourishment directly from those portions of soil which are in immediate contact with their rootlets, and that they die when their food is presented to them in solution. The action of *concentrated* manures, which are said by agriculturists to *burn* the young plants, appears to stand in some connection with this supposition.

The composition of our common river, well, and drainage water from land, may serve to support these conclusions.

A number of excellent analyses of river and well waters has been published by Graham, Miller, and

Hofmann (Chem. Soc. Qu. T. iv. 375), from which it appears that 100,000 gallons, or 500 tons of Thames water, taken from five different places, contain :—

	Thames Ditton.	Kew.	Barnes.	Redhouse, Battersea.	Lambeth.
Pounds of Potash.	7·3	4·71	3·55	10	7·3

The following well waters contain, in 100,000 gallons :—

	Witley.	Critchmere.	Vellwool.	Hindhead.	Barford.	Cosford House.
Pounds of Potash.	2·71	2·5	3	0·7	1·8	6

Thomas Way found in drainage water—that is, in rain-water (which had naturally percolated through the soil), taken from seven different fields, the following constituents (Journal of the Roy. Ag. Soc., vol. xvii. 133) :—

	Grains in 1 gallon = 70,000 grains of water.						
	1	2	3	4	5	6	7
Potash	Trace	Trace	0·02	0·05	Trace	0·22	Trace
Soda	1·00	2·17	2·26	0·87	1·42	1·40	3·20
Lime	4·85	7·19	6·05	2·26	2·52	5·82	13·00
Magnesia	0·68	2·32	2·48	0·41	0·21	0·93	2·50
Iron and Alumina	0·40	0·05	0·10	——	1·30	0·35	0·50
Silica	0·95	0·45	0·55	1·20	1·80	0·65	0·85
Chlorine	0·70	1·10	1·27	0·81	1·26	1·21	2·62
Sulphuric acid	1·65	5·15	4·40	1·71	1·29	3·12	9·51
Phosphoric acid	Trace	0·12	Trace	Trace	0·08	0·06	0·12
Ammonia	0·018	0·018	0·018	0·012	0·018	0·018	0·006

Very similar results were obtained by Dr. Krocker from his analysis of drainage water from Proskau (Lieb. and Kopp's Jahr., f. 1853, p. 742) :—

	Drainage Water (in 10,000 parts).					
	a	b	c	d	e	f*
Organic matter	0·25	0·24	0·16	0·06	0·63	0·56
Carbonate of lime	0·84	0·84	1·27	0·79	0·71	0·84
Sulphate of lime	2·08	2·10	1·14	0·17	0·77	0·72
Nitrate of lime	0·02	0·02	0·01	0·02	0·02	0·02
Carbonate of magnesia	0·70	0·69	0·47	0·27	0·27	0·16
Carbonate of iron	0·04	0·04	0·04	0·02	0·02	0·01
Potash	0·02	0·02	0·02	0·02	0·04	0·06
Soda	0·11	0·15	0·13	0·10	0·05	0·04
Chloride of sodium	0·08	0·08	0·07	0·03	0·01	0·01
Silica	0·07	0·07	0·06	0·05	0·06	0·05
Total solid matter	4·21	4·25	3·37	1·53	2·58	2·47

These drainage waters contain all the substances which rain-water can dissolve out of the soil, and from their composition an idea may be formed of the quantity which a plant during the period of its growth can possibly obtain from such a solution.

Let us assume that on a 2½ acre field 12 million pounds of rain-water fall in a year, and that a third of this quantity dissolves from the soil the same ingredients, in the same proportions, as in the drainage waters analysed by Way. Let us further suppose that these 4 million pounds of water are, during

* **a** Drainage water from land A (a clay soil resting on a subsoil of chalky loam) collected 1st of April, 1853. **b** The same, collected 1st of May, 1853, after a heavy fall of rain (218 cub. in. on the square foot). **c** Drainage water from the same soil, mixed with water from a humus clay soil, with chalky loam as subsoil, collected in October, 1853. **d** Drainage water from land B (tile-drained, subsoil of chalky loam) collected in October, 1853. **e** Water passing through the water furrows from a heavy clay soil, collected in the beginning of June. **f** The same, collected in the middle of August, after heavy rain.

the months of June, July, August, and September, completely absorbed by the roots of a crop of potatoes, and again evaporated from the leaves; then it follows that on four fields of 2½ acres each, the whole crop of potatoes would not receive a single pound of potash; on two others of the same size they would obtain rather more than a pound; and on a seventh 2½ acre field, two pounds.

Now, from an average crop of potatoes on a 2½ acre field, there are obtained 408 lbs. of ashes, in which are contained 200 lbs. of potash.

If, again, we suppose a crop of beet to be grown on the fields, of which Dr. Krocker analysed the drainage water, and also assume that 4 million pounds of rain-water saturated with mineral substances from the soil, are absorbed by the crop, then these plants would receive from this source on four different fields of 2½ acres each, only 8 lbs. each; on another, 16 lbs.; and on a third, 24 lbs. of potash.

Now, an average crop of beet from 2½ acres weighs, with leaves, about 1000 cwt., which contain 1144 lbs. of ashes, of which 495 lbs. are potash!

The quantity of ammonia present in the drainage waters analysed by Way is exceedingly small. It is not very probable that one pound of ammonia in 3½ million pounds of water can exercise any marked influence on vegetation.

In a gallon (70,000 grs.) of Thames water taken from four different places, the quantity of ammonia could not be estimated. In the portion taken at Red-house, Battersea, there were found 3 of ammonia, in 7 million parts of water (Lieb. and Kopp's Jahr., f. 1851, p. 658). By irrigation the Thames water would undoubtedly produce a considerable increase in the crops of hay on many meadows, but certainly not by its ammonia, which is present in this, as well as in all river waters in general, in only very minute quantities.

The amount of phosphoric acid in drain, river, and ordinary well water, is exactly nil. Krocker found in drainage water no phosphoric acid; Way obtained from three, only traces; in two others, he found 12 parts of phosphoric acid in 7 million parts of water; in a third, 8 parts, and in a fourth, 6 parts of phosphoric acid, to the same quantity of water.

From the action of soils already described, it follows that plants must themselves play some peculiar part in the absorption of their food. As organised living structures, their existence is not quite dependent on external causes.

Did land plants receive their food from a solution, they should only be able to take up what this solution contains and brings to them in a certain time, and just in proportion to the evaporation of the water from their leaves. It is quite certain that in the process of assimilation, there is a necessary co-operation between the water which soaks through the ground, and the evaporation which takes place from the leaves of plants; but the ground itself plays the part of a guardian, protecting plants from a hurtful supply. They select from the soil those substances which they require, but which can only pass into the interior of their organisms by the co-operation of a cause which resides within the rootlets.

We frequently find in meadows smooth lime-stones, with their surfaces covered with a network of small furrows. When these stones are newly taken out of the ground, we find that each furrow corresponds to a rootlet, which appears as if it had eaten into the stone.

It is very difficult to explain in what way plants act in causing the solution of mineral substances. As a matter of course, water is indispensable in the operation.

The difficulty of explaining the facts ought not at once to deter us from investigating them in all their bearings, and ascertaining the extent of their influence. Exceptions exist in abundance.

In the case of many water plants whose roots do not come in contact with the ground, there must of course exist other laws for the absorption of their mineral food. As in the case of sea-plants, they must receive it from the surrounding medium; for, wherever a plant grows, it must find all the conditions necessary to its existence.

The investigation of duckweed (Lemna trisulca) offers in this respect some points of interest. This plant grows in still waters, in ponds and bogs, floating on the surface, so that its roots are not in contact with the bottom.

From an artificial piece of bog in the botanic garden of this place (Munich), a quantity of this plant was collected, dried, incinerated, and the amount of ash determined. From 10 to 15 litres ($2\frac{1}{5}$ to $3\frac{1}{3}$ galls.), of the bog water which was of a slight greenish tint, was at the same time filtered and evaporated to dryness. The ashes, as well as the residue from evaporation of the water, were submitted to analysis. For comparison, the results are here placed together.

	Ash of Duckweed. 100 parts of dried duckweed, give 16·6 parts of Ash. In 100 parts of the Ash heated to low redness, are contained :—	Evaporated residue from water of the Botanic Gardens. 1 Litre gives 0·415 grm. salts (heated to low redness). In 100 parts of the salts are contained : —
Lime	16·82	35·00
Magnesia	5·08	12·264
Chloride of sodium	5·897	10·10
Chloride of potassium	1·45	——
Potash	13·16	3·97
Soda	——	0·471
Oxide of iron with traces of alumina	7·36	0·721
Phosphoric acid	8·73	2·619
Sulphuric acid	6·09	8·271
Silica	12·35	3·24

The amount of mineral constituents of this plant, as well as of the bog water, must strike others with the same astonishment as it did the first observer. For we could not presuppose that such a plant should so far surpass the majority of land plants in the richness of its mineral constituents. These were certainly taken up by the plant from a solution; but in the process, it is highly deserving of remark, that a power of selection was exercised by the plant.

The comparison of the composition of the ash with the salts left by the water shows, that all the mineral constituents of the latter, with the exception of the soda, are found in the plant, but in very altered proportions; the water contains 45 per cent. of lime and magnesia, the plant only 21 per cent. of both; the water contains 0·72 per cent. of oxide of iron, the plant ten times this quantity. The difference in the phosphoric acid, potash, &c., is not less striking. The soluble mineral constituents were taken up by the plant in the various degrees required for its vital processes, and in no way proportional to the amount present in the fluid.

The amount of mineral matter present in this water is remarkable. It is more than ten times greater than in drainage water, and twenty-five to thirty times greater than in well water. It resembles a mineral water in the kind of salts it contains, and except in bogs is not likely to occur in nature.

The amount of potash, phosphoric, sulphuric, and silicic acids, and oxide of iron, which is found in it, can be easily explained. In such a bog, the remains of dead plants are by degrees collected, the roots of which have received from the soil a quantity of mineral matter. These remains undergo decomposition at the bottom of the pool, and their inorganic elements are dissolved by the aid of carbonic acid, and probably of organic acids, and remain in solution in the water after the surrounding mud and earth have been completely saturated with them. An experiment, in fact, showed, that this potash water lost none of its potash on filtration through earth taken at the distance of a foot from the edge of the basin, whilst it was quickly removed by earth taken from other spots.

In many places the mud from pools, still waters, and many bogs, is highly esteemed as a fertilising agent. It is evident that such mud acts like arable soil which has absorbed as much as it is capable of doing of the soluble elements of food or manure brought in contact with it, and a satisfactory explanation of its effect is found in the quality of the bog water. Finally, it is conceivable that water, in percolating through many field and garden soils, in which the remains of plants have accumulated, and are undergoing decomposition, will dissolve up many substances not usually found in mineral waters.

With the chemical properties of soils just described, there is associated a physical quality, not less remarkable in its nature and influence; viz., the power which they possess of attracting moisture from the air, and condensing it in their pores. It has been long known that earth possesses a strong attraction for watery vapour, but it was to Babo that we were first indebted for the proof that this attraction is only second to that of sulphuric acid, which possesses it in the highest degree. If we fill a flask with air completely saturated with moisture at 20° C. (68° Fahr.), the slightest diminution of temperature will cause the moisture to be deposited in the form of dew; but if a few ounces of earth dried at 35° to 40° C. (95° to 104° Fahr.), be placed in the flask, the moisture will, in the course of a few minutes, be so completely absorbed by it, that no deposit of dew will take place at a temperature even of 8° to 10° C. below 0° (14° to 18° Fahr.). The tension of the watery vapour has sunk from 17^{mm} to less than 2^{mm}.

In very moist air, soil loses its absorbing power for moisture in proportion as it becomes saturated. When perfectly saturated it no longer absorbs any moisture from the air. From air of the temperature of 20° C. (68° Fahr.), containing watery vapour with a tension of more than 2^{mm}, dry earth absorbs moisture, until an equilibrium is established between the tension of the watery vapour in the air, or the force which strives to maintain it in the gaseous state, and the power of attraction in the earth which tends to destroy this state.

A soil which has been saturated with moisture from the air at a given temperature, gives off a certain portion to drier air, or on an elevation of temperature. On the other hand, it absorbs moisture from air still more moist, until an equilibrium is established.

The processes of absorption and evaporation are accompanied by a most important phenomenon. By absorption of moisture the soil is warmed, and by evaporation it is cooled. If we suspend in a vessel with moist air, a linen bag full of dry earth, with a thermometer sunk in it, the quicksilver will be observed to rise in a few seconds. In Babo's experiment the temperature rose, in a specimen of soil rich in organic matter, from 20° to 31° C. (68° to 88° Fahr.); in a sandy soil to 27° C. (80° Fahr.). In like manner, soil which had been partly saturated with moisture from air at 68° Fahr. and 54° dew-point, when placed in air completely saturated with moisture, caused the temperature to rise 3·6° to 5·4° Fahr. Such phenomena as these must exercise a most decided influence on vegetation; for though the above extremes in the elevation of temperature are seldom observed, the intermediate points are of frequent occurrence.

When in a hot summer the surface of the ground is dried, and there is no replacement of moisture by capillary attraction from the deeper strata, the powerful attraction of the soil for the vapours of water in the air provides the means for supporting vegetation.

The vapour of water which is thus condensed by the soil is derived from two sources. During the night the temperature of the air falls; the tension of its watery vapour becomes less; and then, without the temperature of the air falling to the dew-point, there follows, through the attraction of the soil, absorption of moisture (with ammonia and carbonic acid), accompanied by evolution of heat which moderates the cooling of the ground from radiation. In rainless tropical regions, particularly, this phenomenon must be of the most palpable influence. If in our temperate climate its effect is not so striking as in these regions, it is nevertheless not to be regarded as altogether inappreciable. As condensation takes place slowly, the elevation of temperature here cannot amount in many cases to more than fractions of a degree. But it is precisely those fractions which promote the better growth of many plants. The soil by means of this property of absorption becomes warmer, and maintains its temperature more equably than it would otherwise do.

A second source from which the dry soil derives by absorption its moisture, is presented by the deeper lying moist strata. From these a constant distillation of water is taking place towards the surface, accompanied by a corresponding evolution of heat in the upper strata on its absorption. By drainage the water, which rises by capillary attraction, being placed at a greater depth, the dry soil now receives from the lower strata a quantity of moisture in the form of vapour, which supplies the wants of plants, and at the same time raises the temperature of the ground.

In the above facts we recognise one of the most remarkable natural laws. *The outermost crust of the earth is destined for the development of organic life,* *and its broken particles are endowed, by the wisest arrangement, with the power of collecting and retaining all the elements of food which are essential for the purpose.* This power preserves to the productive soil, even in apparently the most unfavourable circumstances, the conditions of fertility either contained therein, or bestowed upon it.

LETTER IV.

The Belief in the value of Humus no longer exists; its Action now ascertained—Effect of the Salts of Ammonia not dependent on their Nitrogen—The action of Nitrates like that of the Salts of Ammonia—Experiments with Nitrates and Chlorides—Experiments with Salts of Ammonia alone, and with the addition of Common Salt—Solubility of the Earthy Phosphates in solutions of Chlorides of Ammonium and of Sodium, and of Nitrate of Soda—Experiments with these Salts—Their Solvent Action similar to that of Carbonic Acid water—The Salts of Ammonia are decomposed in the soil; their twofold action—Difference in the Comportment of Salts of Potash and of Soda in the Soil—Potash extracted by Sulphate of Ammonia from silicates—Application of the Action of Chili Saltpetre, Salts of Ammonia, and Chloride of Sodium to explain the increase of fertility in the soil, and the Nutrition of Plants.

Up to a few years ago, scientific agriculture taught, and all practical men firmly believed, that the productiveness of a soil was dependent on the quantity of humus, or carbonaceous remains of a preceding vegetation, contained in it. Without raising doubts on the efficacy in certain cases of the organic matter in farm-yard manure, it may be asserted that nobody who possesses any knowledge of the matter, now believes that the produce of a field in carbonaceous substances bears any proportion to the amount of humus in the soil, and that its fertility can in reality be estimated, as was formerly supposed, by this humus.

We have now obtained more exact information on the part played by humus in vegetation, and can predict in what cases its presence will be beneficial or hurtful. We know that it is only useful when the soil contains in sufficient quantity the fixed mineral constituents serviceable to plants; and that it is without action when these are wanting. By its decomposition in the soil, humus forms a source of carbonic acid, by which the fixed elements of food are rendered soluble, and capable of being distributed in all directions.

In his remarkable experiments on the action of the salts of ammonia, Lawes obtained in twelve years from an acre of the same field, by the use of mineral substances and salts of ammonia, produce in wheat and straw, amounting to 51,995 lbs. From a second acre manured in the same way, the return reached 53,182 lbs. By the use of pure mineral manures, there was obtained from these two fields a greater amount of produce, to the extent of 18,525 lbs. in one case, and of 19,713 in the other, than from an unmanured field of similar size. It is quite certain that by the employment of farm-yard manure, a similar, if not higher, return would have been obtained from both fields. There can, however, be no doubt that in both cases the salts of ammonia had taken the place, and produced the effect of the decaying organic matter of this manure; and it is not improbable that the same cause was in operation in augmenting the produce.

It has been abundantly proved by facts, that the action of the salts of ammonia is no way proportional to the amount of nitrogen in them; hence it is evident that the salts as such, or the acids of the salts, must take part in the effect produced. The precise nature of this co-operation is, however, not yet distinctly made out; and from this cause has arisen the great discordance in the views of the peculiar action of the salts of ammonia. Whilst some hold that the action can only be referred to the nitrogen, because the acid can be changed without thereby materially altering the effect; others assert that the soil already contains so much ammonia, that the increase of produce cannot be attributed to the small quantity of nitrogen added in the salts of ammonia. They maintain that an acre of ground which contains in its upper ten inches of soil 10,000 lbs. of ammonia or nitrogen, could not have its fertility increased two-fold by the addition of 30 to 60 lbs. of ammonia. As in such a soil there was no want of nitrogen, the cause of the increased fertility must be sought for in something else.

The case is much the same with the action of nitrates as with that of the salts of ammonia. Nitrate of soda exercises a powerful effect, in certain cases, on the increase of grain and straw, and in others it is valueless. The experiments of Kuhlmann have shown that the bases also of these salts play some part in the action. From a meadow manured with 250 kilogrammes (550 lbs.) of nitrate of soda, an increase of crop to the amount of 2053 kilo. (4516 lbs.), per hectare ($2\frac{1}{2}$ acres), was obtained; whilst from another portion of the same meadow, to which was applied the same quantity of nitrate of lime, (containing $1\frac{1}{4}$ per cent. more nitric acid), there was an increase of only 693 kilo. (1524 lbs.). Consequently the produce from nitrate of lime was $\frac{2}{3}$ less than from the soda salt. If we ascribe the increase in the crop to the nitric acid, then the effect of the two salts is quite incomprehensible.

The action of common salt appears in many cases equally incomprehensible. In 1846, Kuhlmann obtained from 200 kilo. (440 lbs.) of sulphate of ammonia an increase of hay, amounting to 2533 kilo. (5572 lbs.); a similar quantity of sulphate of ammonia, with the addition of 133 kilo. (292 lbs.) of common salt, gave an increase of 3173 kilo. (6980 lbs.) of hay. There were consequently 640 kilo. (1408 lbs.) more hay obtained by the addition of the common salt, than from the employment of the sulphate of ammonia alone.

It might be supposed, that the want of a chlorine compound, which is contained in not inconsiderable quantity in meadow plants, was the reason, in the case of the common salt, of the increase of produce; but a similar difference, as in the above cases, was found in two other experiments, which Kuhlmann made, in 1845 and 1846, with sal-ammoniac alone, and with sal-ammoniac and common salt. The piece of meadow manured with 200 kilo. (440 lbs.) of sal-ammoniac gave in the two years 3700 kilo. (8140 lbs.) per hectare ($2\frac{1}{2}$ acres), more hay than a piece of the same extent which was unmanured. From another portion, to which were applied 200 kilo. of sal-ammoniac and 200 kilo. of common salt, 5687 kilo. (12,511 lbs.) of hay were obtained. Hence, by the use of common salt, there was an increase of 1087 kilo. (2391 lbs.), or a half more than from the sal-ammoniac alone. 200 kilo. of common salt alone, without sal-ammoniac, produced an increase of 1606 kilo. of hay, the difference between the two numbers (1987 and 1606 kilo) is not great enough to exclude the idea, that each salt has acted, just as if the other had not been present, or, in other words, that each salt has a special action of its own.

In the summer of 1857, the effect of salts of ammonia by themselves, and mixed with common salt, on summer barley, was tried by the General Committee of the Agricultural Society of Bavaria, in a series of experiments made at Bogenhausen, in the neighbourhood of Munich. For this purpose, 18 plots, each of 1914 square feet in extent, were marked off in a field which had gone through the usual rotation of crops, having been, three years previously, manured with common farm-yard manure, and having borne rye, and then two crops of oats. Four of these plots were manured with salts of ammonia; one remained unmanured; to four others were applied the same quantity of ammonia salts, and at the same time, to each 3080 grm. ($6\frac{1}{2}$ lbs.) of common salt. Each plot received the *same amount of nitrogen* in the ammonia salts.

In estimating the quantity of manuring matter to be employed, it was assumed that 400 lbs. (= 440 lbs.

Eng.) of guano per English acre, corresponded to the full measure of farm-yard manure usually applied; this gives twenty pounds of guano for one of the plots. A good sample of guano was selected for the experiments, and on being submitted to analysis, was found to consist of 14·53 water, 33·38 ash, and 52·10 organic matter, of which 15·39 was ammonia. Twenty pounds of this guano, therefore, contained 3·07 lbs. of ammonia. In the ammonia salts used, analysis gave in

Carbonate of Ammonia . . .	29·84	per cent.	Ammonia.
Phosphate ,, ...	21·96	,,	,,
Nitrate ,, . . .	19·11	,,	,,

In correspondence with this percentage of ammonia, there were applied to two of the plots, I. and V., 10½ Bavarian pounds (= 13 lbs. Eng.) of carbonate of ammonia; to two others, II. and VI., 7½ lbs. (=9 lbs. Eng.) of nitrate of ammonia; to two others, III. and VII., 12lbs., (= 14⅔ lbs. Eng.) phosphate of ammonia. Two plots, IV. and VIII., received each 12 lbs. (= 14⅔ lbs. Eng.) of crystallised sulphate of ammonia; another, 20 lbs. (= 24⅔ lbs. Eng.) of the analysed guano. The plots V., VI., VII., VIII., received each at the same time 3080 grm. (= 6⅔ lbs. Eng.) of common salt. I will here communicate these experiments in full, as they offer other points of interest, in addition to the action which must be ascribed to the common salt.

Produce of barley (grain and straw), from the four plots manured with *ammonia salts* alone:—

	Grain.		Straw.	
	grm.	lbs. Eng.	grm.	lbs. Eng.
I. . . . . =	6335 =	14·0	16205 =	35·6
II. . . . . . =	8470 =	18·6	16730 =	36·8
III. . . . . =	7280 =	16·0	17920 =	39·5
IV. . . . . . =	6912 =	15·2	18287 =	40·2
The unmanured plot gave =	6825 =	15·0	18375 =	40·4

Produce of barley (grain and straw) from four plots manured with *ammonia salts* and *common salt*:—

	Grain.		Straw.	
	grm.	lbs. Eng.	grm.	lbs. Eng.
V. . . . . =	14550 =	32·0	27020 =	59·5
VI. . . . . =	16510 =	36·3	36645 =	80·6
VII. . . . . =	9887 =	21·7	24832 =	54·6
VIII. . . . . =	11130 =	24·5	27969 =	61·5

Increase of produce in plots V. to VIII., manured with common salt and salts of ammonia, above that of plots I. to IV., manured with salts of ammonia alone:—

	Grain.		Straw.	
	grm.	lbs. Eng.	grm.	lbs. Eng.
V. . . . . =	8255 =	18·2	10814 =	23·8
VI. . . . . . =	7770 =	17·0	19915 =	43·8
VII. . . . . =	2607 =	5·7	6912 =	15·2
VIII. . . . . . =	4218 =	9·3	9782 =	21·5

In instituting experiments in practical agriculture with manures, the increase of crop is generally the only object kept in view. If this object be attained, the experiments are said to be successful. In this sense, the above experiments, both with and without common salt, are unsuccessful; for the returns scarcely reach average crops. The object with which they were made was not, however, to obtain a greater crop than the average, but to investigate the action of the salts of ammonia alone, and with the addition of common salt. In this respect they agree sufficiently to banish all doubt as to the physiological importance of common salt to the Bogenhausen fields. In every case the crop was increased by the addition of common salt. Common salt when used with carbonate of ammonia, doubled the produce of grain; and with nitrate of ammonia, it raised the return of corn 90 per cent.,—and of straw 120 per cent.

As the mixture of nitrate of ammonia and common salt contains the elements of nitrate of soda, a counter experiment with the latter salt on a plot of the same field, made at the same time, is of much interest. The plot manured with 16 lbs. (= 19⅔ lbs. Eng.) of nitrate of soda, gave 12320 grm. (= 27 lbs.) grain, and 32480 grm. (= 71½ lbs.) straw; and by the addition of 5½ lbs. (= 6⅔ lbs. Eng.) of common salt, the grain increased to 17920 grm. (= 39½ lbs.), and the straw to 35780 grm. (= 78⅔ lbs.). Common salt had, therefore, also increased the action of Chili saltpetre. A mixture of these two salts produced a still higher yield of grain, than a mixture of common salt and nitrate of ammonia, which contained the same proportion of nitrogen. The experiment with 20 lbs. (= 24⅔ lbs.) of guano, on a plot of the same size, gave 17200 grm. (= 38 lbs.) grain, and 33320 grm. (= 73⅓ lbs.) straw.

It is quite certain, that in the action of the guano, which produced the crop next highest after the Chili saltpetre, an unmistakable part was played by the ammonia contained in it. On the other hand, however, the experiments with carbonate and nitrate of ammonia show, that a quantity of ammonia, or nitrogen, equivalent to that in 20 lbs. of guano, and employed under the same conditions, was almost without effect.

I will not, by further pursuing this subject, weaken the significance of the most important fact brought out by these experiments with the salts of ammonia, viz., that common salt, in reality, exercises a favourable action on the growth of straw plants in the Bogenhausen fields, and increases the mass of vegetable matter in them.

This fact is indeed not new in agriculture; but in a number of cases, in which common salt has been shown to be a useful addition to other manures, its action has not been sufficiently distinct and decided; and it is a rule in natural inquiries that a fact must first of all be firmly established, before we proceed to seek its explanation.

The action of common salt is evidently very similar to that of the salts of ammonia and nitrate of soda; but if we refer the effect of these last two substances to their nitrogen, because ammonia and nitric acid are food for plants, then this explanation will not hold good for common salt. For neither this salt nor chlorine enters as an element into the structure of plants, and it cannot be asserted that either of them is necessary, although both are frequently met with as constituents of the ashes of plants.

The most recent observations on the comportment of the soil towards the food of plants show how slight is the knowledge we possess of their mode of nourishment, and of the part which the soil, by its physical condition, plays in it. The comportment of the salts of ammonia, of chloride of sodium, and of nitrate of soda, towards the earthy phosphates in the soil, may perhaps assist us in throwing some light on their action, or on one of their actions, on the growth of plants.

Like carbonic acid water, the sulphate, as well as other soluble salts of ammonia, possesses the property of rendering the earthy phosphates soluble in water.

We know of no other way in which the earthy phosphates are dispersed through the soil than by means of carbonic acid water. If it is true that one of the chief effects of humus, or the decaying remains of plants in soils or in manures, consists in its forming a source of carbonic acid, with which the air and water in the ground is enriched; if it is also true that this carbonic acid water renders the earthy phosphates soluble, and thus contributes to their distribution in the soil, then there can be no doubt that the salts of ammonia, which possess the same solvent property, can in this respect replace the organic matters, and thus exert an equally favourable influence on the growth of plants.

The same solvent property is also possessed among the salts of soda by Chili saltpetre and common salt.

It has been recently shown that these two salts, even in the most dilute solutions, dissolve earthy phosphates to a very appreciable extent, and that consequently they must play a part in the process of the nutrition of plants, similar to that which is ascribed to carbonic acid water (to the humus) and to the salts of ammonia.

From direct experiments it appears, that 100 kilo. (= 220 lbs.) of sulphate of ammonia in solution in 45,000 litres (= 9,900 galls.) of water can dissolve 3600 grm. (= 7.9 lbs.) of bibasic phosphate of lime (PO_5, 2CaO, aq.) such as exists in bones that have been acted on by sulphuric acid; or, in other words, 100 lbs. of sulphate of ammonia in 4,500 gallons of water—dissolve nearly 4lbs. of phosphate of lime. In like manner 100 lbs. (= 123 lbs. Eng.) of common salt, in 50,000 litres (= 11,000 galls.) of water, dissolve 3,300 grm. (= 7⅓ lbs.) of bibasic phosphate of lime; and 100 kilo. (= 220 lbs.) of nitrate of soda, in 33,400 litres (= 7,348 galls.) of water, dissolve 2,630 grm. (= 5¾ lbs.) of the same phosphate.

Tribasic phosphate of lime (PO_5, 3CaO) is much less soluble in these fluids.

100 kilo. (220 lbs.) of	In solution in water in	Dissolve of tribasic phosphate of lime, PO_5, 3 CaO.
Sulphate of ammonia. . .	54,000 litres (=11,880 galls.)	3400 grm. (=7½ lbs.)
Common salt. . .	50,000 ,, (= 11,000 ,,)	1500 ,, (=3⅓ ,,)
Nitrate of soda .	33,300 ,, (= 7,326 ,,)	1200 ,, (=2⅗ ,,)

The seeds of the cereals, particularly wheat, contain phosphate of lime, and in preponderating quantity phosphate of magnesia. In many kinds of wheat the quantity of phosphate of magnesia is four times, often ten times, greater than that of the phosphate of lime; and in like manner in the grain of rye, oats, and barley, the magnesia salt exceeds very greatly the phosphate of lime. These proportions are so constant that they cannot be ignored in the cultivation of these plants. The comportment of the salts above-mentioned towards phosphate of magnesia and ammonia, and phosphate of magnesia, appears, therefore, of special interest.

100 kilo. (220 lbs.) of	In solution in water in	Dissolve of phosphate of Magnesia, PO_5 3 MgO.
Nitrate of soda .	33,300 kilo. (= 73,260 lbs.)	2160 grm. (=4¾ lbs.)
Common salt . .	50,000 ,, (=110,000 ,,)	3790 ,, (=8⅓ ,,)

The solubility in the same fluids of phosphate of magnesia and ammonia is still greater.

100 kilo. (220 lbs.) of	In solution in water, in	Dissolve of phosphate of magnesia and ammonia, PO_5, 2 MgO, NH_4O.
Sulphate of ammonia	33,300 litres (= 7326 galls.)	4113 grm. (=9 lbs.)
Common salt . .	50,000 ,, (=11,000 ,,)	6170 ,, (=13½ ,,)
Nitrate of soda .	33,300 ,, (= 7326 ,,)	4655 ,, (=10¼ ,,)

The quantity of the earthy phosphates taken up by the above fluids does not rise in proportion with the amount of salts in solution, but rather on the contrary with the dilution of these fluids.*

It is quite conclusive from these facts, that water containing a very small quantity of common salt, nitrate of soda, or a salt of ammonia, acquires thereby the power, (which alone it does not possess, or only in a slight degree) of dissolving phosphoric acid, in the form of earthy phosphates. These feeble solutions, therefore, react towards earthy phosphates like solutions of carbonic acid in water. 100 kilo. (= 220 lbs.), for example, of sulphate of ammonia produce the same solvent effect on phosphate of lime as 4720 litres (= 1038½ galls.) of carbonic acid in solution in water; and 100 kilo. of common salt dissolve as much phosphate of magnesia and ammonia as a watery solution of 3456 litres (= 760⅓ galls.) of carbonic acid.

Direct experiments prove, that a very dilute solution of the same salts, take up phosphoric acid from a soil which contains earthy phosphates in *excess*, and that this dissolved acid is again given up by this solution to a similar soil which is *not* already saturated with phosphoric acid.

If we submit to a close scrutiny the comportment of

* 1000 C. C. of fluid, containing at 57° F.	Dissolve of PO_5, 2MgO, NH_4O.	For 1 grm. of salt.
2·2 grm. NH_4OSO_3	76·7 milligrm.	34·9 milligrm.
3· " "	113·0 "	37·6 "
10· " "	147·0 "	14·7 "

the salts of ammonia, nitrate of soda, and common salt towards soils, we find that not one of these salts acts in the same form in which it has been added to the ground.

The salts of ammonia are immediately decomposed by the soil; the ammonia is retained, whilst the acid enters into combination with lime, magnesia, alkalies, or, in short, with any basic substance in immediate contact and capable of combining with it.

The action of these salts is therefore of a two-fold nature. On the one hand, they enrich the soil with ammonia; on the other, their acid gives rise to new compounds which come into operation. The alkalies and alkaline earths which combine with the acid acquire thereby a greater degree of solubility, and are more readily diffused through the soil. If the ground is rich in magnesia or lime, the salts of these bases are formed; but their influence, with the exception of that of gypsum, on certain plants cannot be estimated very high. The use of sal-ammoniac, instead of sulphate of ammonia, gives rise to chloride of magnesium, and chloride of calcium, which act rather unfavourably than otherwise on vegetation. That salts of these bases are generated by the action of soils on salts of ammonia, and that the new salts exert no particularly favourable influence on the increase of produce, are facts on which no doubt can rest.

If, however, portions of the soil containing in some places phosphate of lime or of magnesia in the form of coarse grain, or powder, or bone earth, come in contact with these ammoniacal fluids, then there follows solution of these earthy phosphates, and their consequent diffusion through the soil.

Potash salts resemble those of ammonia in the rapidity of their decomposition in contact with soils; but the comportment of soda salts is quite different.

On slowly filtering a solution of nitrate of soda (containing one-fifth per cent. of salt) through an equal volume of Bogenhausen loam, half of the salt passes through unabsorbed, whilst the other half is converted into nitrate of lime and nitrate of magnesia. Under the same circumstances three-fourths of a solution of chloride of sodium remain undecomposed.

If, therefore, a field is manured with nitrate of soda or common salt, and the soil becomes saturated with a dilute solution of these salts formed by rain, a great portion of them will remain unchanged in the ground, and must exercise on the moist soil an action which, though in itself feeble, becomes powerful by its continuance.

Like the salts of ammonia, or a watery solution of carbonic acid produced by the decay of organic matter in manures, a solution of these salts, wherever they come in contact with spots containing accumulations of earthy phosphates not fixed by the soil, must become saturated with these phosphates, and thus convert them into a condition in which they can be diffused through the ground. If the earthy phosphates, when thus diffused in solution, come in contact with other portions of soil not yet saturated with these salts, those portions absorb and fix these earthy phosphates, and the chloride of sodium or nitrate of soda retains, a second time, or more frequently, the power of exercising the same solvent and distributing action over the earthy phosphates until the ultimate and complete conversion of the chloride and nitrate into a lime or magnesia salt.

When we consider how much the fertilising effect of bone earth is increased by the greater solubility and capability of distribution in the soil communicated by the action of sulphuric acid, we cannot too highly estimate the significance of the properties, just described, of the salts of ammonia, chloride of sodium, and Chili saltpetre.

The most abundant application of earthy phosphates in coarse powder, can in its effects bear no comparison with a much smaller quantity which, in an infinite state of division, is dispersed through every portion of soil. A rootlet requires at the spot where it touches the soil a most minute amount of food; but it is necessary to its functions and its very existence, that this minimum be found exactly at this spot. For if the food of plants be not soluble in water, then is any excess at any other spot as valueless to the function of nutrition of this rootlet as if it did not exist at all in the soil. Now, the salts of which we have been speaking, possess the property of conveying these elements of food from the spot in which they exist in superabundance to others in which there is a deficiency; and even though their elements contributed in no way directly to the process of nutrition, yet, these salts must nevertheless exercise a marked influence on the increase of produce.

When the sulphate of ammonia and the Chili saltpetre have been completely transformed into lime and magnesia salts, and the chloride of sodium into chloride of calcium and chloride of magnesium, this action then ceases; and a second dose of these salts is then necessary to reproduce the action.

If the effect of the salts of ammonia depends on the ammonia, we can scarcely comprehend why, after a large application of them, that portion which has not acted during the first year should not in the second come into operation, since this latter portion is presented in the soil to plants in the same form as the portion which produced its effect during the first year.

Sulphate of ammonia produces on alkaline silicates a reaction similar to that on earthy phosphates. If this salt, in very dilute solution, is brought in contact with soil saturated with silicate of potash, and which does not give up a trace of its potash to water alone, it instantly dissolves a certain quantity of this alkali, which may be easily detected by the ordinary re-agents.

It is evident that the agriculturist, by the proper application of the chemical action of common salt, Chili saltpetre and ammonia salts, accomplishes the same object as by the mechanical operation of ploughing, and by the action of the atmosphere in fallow.

We should be committing an error, if, judging from similarity of solvent properties, we concluded that common salt must have the same effect as a corresponding quantity of nitrate of soda. We know that, as a rule, in these cases, the common salt is converted into chloride of calcium, and the Chili saltpetre into nitrate of lime; and the experiments of Kuhlmann have taught us, that chloride of calcium by itself is absolutely ineffective, or rather is hurtful in the cultivation of plants, whilst nitrate of soda contributes materially to the increase of a hay crop. Nitrate of soda, consequently, acts favourably in two ways; chloride of sodium only in one. Further, land plants can bear a considerable quantity of nitrate of soda in the soil, whilst chlorine compounds, beyond a certain very narrow limit, are decidedly hurtful.

We designate as manures all substances which increase the produce of our fields, without knowing whether many of these may not simply act, by rendering the food already existing in the soil more capable of absorption and assimilation. The simple fact of their favourable influence on vegetation, is not yet a proof that they have acted directly as food. We compare the work which the plough performs, to the mastication of food, for which nature has provided animals with a particular instrument; and, as may be seen from the experiments described above, many substances, such as common salt, nitrate of soda, and ammonia salts, independently of the action which is due to their own elements, play a peculiar part, which may be compared to the digesting action of the stomach, and in which they can partly replace each other; and inasmuch then as they prepare the food existing in the soil for the process of nutrition, and render it more fit for assimilation, they must necessarily exert a powerful influence on the growth of plants.

We can now understand, why these salts exercise a favourable action in cultivation only on certain soils, and why on a second or third application of them, the same effect is only partially, or not at all reproduced.

An agriculturist in possession of fields containing abundance of phosphates, but unequally distributed through them, would, were all other conditions the same, undoubtedly increase the activity of these phosphates, and thereby augment the produce of his fields, if he possessed the means of withdrawing the basic phosphates from the soil and restoring them in the form of superphosphate. These means he actually employs, when he manures his fields with Chili saltpetre, ammonia salts, or chloride of sodium.

LETTER V.

No free Ammonia in the Soil—The amount of Food obtained from the soil by plants is in proportion to the absorbent Root-surface—The early development of Roots due to the accumulation of Nourishment in the surface soil—Estimations of the quantity of Ammonia in our cultivated fields—A deficient crop not due to the Absence of Ammonia in the soil—Experiments with salts of Ammonia; the crops only slightly increased thereby—Increase of produce due to accompanying Minerals—Experiments of Lawes and Kuhlmann with Salts of Ammonia, &c.—The fertility of a field dependent on the sum of the Mineral matters in it—The activity of these Minerals increased within a given time by the Salts of Ammonia—The soil more rapidly exhausted by their use unless there is a restoration to it of the removed Mineral matters.

THE soil contains a certain quantity of nitrogen in the form of ammonia and of nitrogen compounds derived from plants and animals.

The observations of Thomson and of Huxtable, and particularly the valuable memoirs of Way, have established the fact, that the carbonate of ammonia of rain water and of manures, and that existing in ammonia salts, are absorbed and so firmly fixed by the soil, that no free ammonia can be present in it. As neither pure nor carbonic acid water can withdraw this fixed ammonia from the soil, it is self evident that, in the nutrition of plants, the rootlets must extract it directly from the soil.

If we now imagine that plants receive all the nitrogen they require for their development not from the air but from the soil, it is clear that every portion of soil must contain the necessary quantity of ammonia or nitrogen for their vital processes; and plants would not attain their maximum development, if they found in those portions less than the roots could absorb and the plant appropriate. Were all other conditions for the formation of grain present, they would then produce a smaller quantity, or grain of a lighter weight.

The productiveness of a field, in so far as it is dependent on nitrogen, would be in proportion to the sum of this element contained in the soil, and to that portion of this sum which is present in each transverse section of the soil from the surface downwards. In whatever spot the rootlets cannot find nitrogen, they would therefore at that spot absorb none.

From two fields, containing from the surface downwards the same quantity of nitrogen, and supposing all the other conditions of growth to be given, it will be found that two plants will receive unequal quantities of nitrogen, if their absorbent surface of rootlets is unequal in extent. The plant with double extent of absorbing root surface will take up twice as much nitrogen as the other. This proportion holds good for all the elements of food in the soil.

From a field which contains only half the quantity of food which is present in another, a plant with a double proportion of rootlet surface will receive as much nourishment as a plant with only half the rootlet surface obtains from the second field.

These propositions are self-evident, and may afford an explanation in many cases of one of the leading effects of manures on our fields. For, an accumulation of nourishment in the upper layer of the field enables plants, during the first period of their development, to send out ten-fold, perhaps a hundred-fold more absorbing rootlets than they otherwise would have done, and their later growth will be in proportion to the greater number of rootlets thus gained, by which they are enabled to seek and appropriate the food distributed sparingly throughout the deeper layers.

We possess as yet no investigation of the number of rootlets and the extent of their absorbing surface in our cultivated plants, and cannot therefore with any degree of certainty fix the quantity of ammonia which must necessarily be present in each transverse section of soil to satisfy the full requirement of nitrogen in the different classes of plants.

If we now accept, on the grounds mentioned in the next letter, that each square millimetre of the transverse section of a field must contain ½ a milligramme of ammonia, in order to furnish to the rootlets of a wheat plant all the nitrogen which it requires for its full growth, it follows that 10,000 lbs. (or 0·12 to 0·13 per cent.) of ammonia must be present in the soil of a hectare (2½ acres) of land within the depth reached by the chief roots.

If we compare with the above the amount of ammonia or nitrogen, ascertained with certainty by numerous analyses to exist in the soils of different countries, it appears that a depth of even ten inches of the greater number of our cultivated fields furnishes much more than this quantity.

As our cultivated plants undoubtedly absorb through the leaves as much nitrogenised food in the form of ammonia and nitric acid from the air as well as dissolved in rain and dew, as uncultivated plants which receive no nitrogenised manure from the hands of man; we can therefore conceive that the agriculturist will seldom have to seek the reason of his poor crops in a deficiency of ammonia or nitrogenised food alone, and that he must first of all direct his attention to certain other conditions in order to improve his harvest.

A knowledge of the quantity of ammonia or nitrogen in a soil is, therefore, not sufficient to enable us to judge of its fertility or capacity for production. For, even though a better crop be obtained from many fields by the application of ammonia, on by far the great majority of others, the largest quantities of this food produce no effect; because though the nitrogen must indeed be there, and takes part in the formation of the vegetable mass, yet it produces by itself no effect, when the conditions are awanting which render it active.

The experiments of Schattenmann made in 1843 in Alsace, are in this respect very instructive. Wheat fields manured by him with salts of ammonia gave a smaller return of grain than another portion of the same land which had received none of this manure. In like manner the experiments of the General Committee of the Agricultural Society of Bavaria in 1857 (see p. 57), show that the produce of barley in grain and straw was rather reduced than otherwise in a field to which carbonate of ammonia had been applied; and that the use of sulphate, phosphate, and nitrate of ammonia raised the produce only a few per cents. A quantity of guano containing the same amount of ammonia as these salts gave on the same field three times as much grain, and twice as much straw as the unmanured land.

It is obvious that the proximate cause of the powerful action of the guano in this case must be sought for in those matters which in it accompany the ammonia; for, as we have just stated, a quantity of ammonia equal to that of the guano produced no marked effect on the same field, in the same year, and with the same kind of crop.

It is clear that a field which either originally contained, or has had added to it, a sufficient quantity of the substances that accompany ammonia in guano, would, on the subsequent application of the salts of ammonia, produce an equally good crop as it would have done with the guano, and better than would have been the case without the aid of the ammonia. In such a case, however, it would be a hasty conclusion to ascribe the higher return to the action of the ammonia alone, because in the years of greater increase the salts of ammonia had been exclusively used.

The experiments of J. B. Lawes, in the years 1844 to 1855, give practical proofs of the truth of this view. He manured a wheat field with superphosphate of lime (560 lbs. per acre), and with silicate of potash (220 lbs.), and in the eleven following years only with ammonia salts (sulphate of ammonia and chloride of ammonium), and reaped on an average from it a half more grain and straw than from another piece of unmanured land of the same size which, during the same years, had been sown with wheat.

These results fully agree with those of Kuhlmann's experiments in 1844 to 1846, with salts of ammonia on a meadow.

From a meadow which had been manured with sal ammoniac, he obtained an increase of 645 parts of hay for every 100 parts of the salt employed. In the same year, from a second meadow, to which sal ammoniac had been also applied, but with the addition of phosphate of lime, he reaped 1666 parts of hay for every 100 parts of sal ammoniac; consequently, the produce was 2½ times more than was obtained without phosphate of lime.

The importance of the addition of fixed mineral food to the increase of crops, and to the duration of the fertility of our fields, will at once be evident to the most prejudiced from another series of experiments by Lawes.

During the period that the experiments already mentioned were in progress, Lawes had applied, on a third field, for three years, fixed mineral matters, and for nine years, salts of ammonia; in 1846 it remained unmanured. This field had, therefore, received two applications of ammonia salts less, and two of mineral manures more than the second field.

The following was the produce per acre of the three fields :—

	Grain and Straw.
I. Unmanured field produced	34,272 lbs.
II. Field manured 1 year with mineral substances, and 11 years with salts of ammonia . .	54,408 ,,
III. Field manured 3 years with mineral substances, and 9 years with salts of ammonia . . .	55,704 ,,

Although the third plot had received above 700 lbs. of ammonia salts per acre less than the second, its produce had nevertheless increased by half a crop. These facts show in the most undoubted manner, that even on ground so rich in the fixed constituents of food for wheat, as to furnish during twelve continuous years, without any manure, a yearly medium crop of 2856 lbs. of grain and straw, the greatest supply of salts of ammonia, with an insufficient replacement of the mineral substances removed in the crops, produced a smaller amount of grain and straw than when these minerals were more fully returned to the soil. They show further that the salts of ammonia as manure were rendered unnecessary exactly in proportion to the supply of fixed mineral substances; for the smaller quantity of ammonia applied to the third field gave, not a correspondingly smaller crop, but on the whole a higher return than the larger quantity of this substance on the second field which had received mineral manure only in the first year.

The effect of mineral substances as manures is apparent by comparing the produce of Plots II. and III. in the different years.

In the year 1850 Plot III. had been manured for the third time with 300 lbs. of carbonate of potash, 200 lbs. of carbonate of soda, 100 lbs. of sulphate of magnesia, 200 lbs. of bone earth, 150 lbs. of sulphuric acid, and in the five following years had received only salts of ammonia.

Plot II. had only once (1844) been manured with superphosphate of lime and silicate of potash, and in the eleven following years with salts of ammonia alone.

The produce of these plots from the year 1850 was the following:—

	Produce of grain and straw in lbs.				
	1851	1852	1853	1854	1855
I. Unmanured plot . .	2710	2457	1772	3496	2860
II. In 1844 received mineral substances, then up to 1855 ammonia salts .	5036	4107	2691	5808	3779
III. In 1844, 1848, 1850, received mineral substances, then up to 1855 ammonia salts . .	4985	4162	3578	7003	5074
OR,					
I.	1000	1000	1000	1000	1000
II.	1850	1630	1500	1690	1520
III.	1800	1690	2010	2000	1770

We see from these numbers that Plot III., after receiving in 1850 a large supply of mineral manure, produced in the two following years no greater crop than Plot II., to which no such excess had been applied. From this absence of any marked effect from the mineral manure, the inexperienced agriculturist might at once believe himself entitled to conclude that the plot already contained a sufficient quantity of these substances, and that, therefore, a further supply was unnecessary, and a piece of extravagance. These experiments, carried out with so much perseverance, prove, however, the unsoundness of such a conclusion. They show that not one particle has been inefficient, but that their action was only apparent after their distribution in the soil had been effected. They show that these mineral substances by themselves require a longer time to become active than when applied in the form of farm-yard manure, which supplies in its organic matter a source of carbonic acid as the natural solvent and distributor of its fixed constituents. The effect of the mineral food exhibited in the increase of produce became apparent only in the fourth year (1853), and its continuance was still evident in the most visible manner in the sixth year.

Whilst the ammonia salts increased the produce of the second plot (which had seven years previously received mineral manure) in the year 1853 one-half more than that of the unmanured plot, the produce of the third plot, with the same quantity of ammonia, was twice as high. In the year 1854, its produce exceeded that of the second plot by 31, and, in 1855, by 45 per cent.

It is hardly possible to find another cause for the difference between the two wheat fields manured with ammonia salts, than that the one was richer than the other in the mineral food for the wheat plant. Nothing can be more positive than that the produce of both fields bore no proportion to the quantity of ammonia applied.

As the fixed mineral constituents incorporated with the third plot in the year 1850 must be regarded as the proximate cause of its increased produce in the years 1853 to 1855, there can be no doubt that the mineral matters (560 lbs. superphosphate of lime, and 220 lbs. silicate of potash), applied in 1844 to the second plot, were equally the proximate cause of the greater return obtained from it in the eleven following years than from the unmanured plot.

With fields under conditions so identical as the experimental plots of Lawes, it cannot be supposed that the third plot could possibly have borne a larger crop in 1853, 1854, and 1855, than the second, had it not contained a larger amount of active mineral matters than the latter; and had the sum of the active mineral substances in the second plot not exceeded that in the unmanured, the increase and continuance of the crops from this second plot would also have been impaired.

It follows, therefore, as a natural consequence, that the crops from the unmanured plot are also proportional to the sum of the active mineral constituents in the soil. Had this sum been smaller, the deficiency would have been evident in the diminution of the crops. With the increase of these mineral matters in the second field, the crops also increased by the aid of the salts of ammonia; and a further quantity of these substances, applied to the third plot, was followed by a still larger crop from that plot, notwithstanding that it had received less ammonia than the second plot.

It is further evident, from the above, that the crops, and the increase in them, were dependent on the sum of the mineral matters in the three plots, and on that portion of this sum, which had been rendered fit for absorption by the action of the salts of ammonia. Without the supply of fixed mineral substances to the second and third plots in Lawes' experiments, they would have been, after the lapse of a few years, precisely in the same condition as those of Schattenmann, from which there was obtained no increase of grain by the application of the salts of ammonia. When by the supply of salts of ammonia, or Chili saltpetre, the produce of corn and straw in a field is increased, the proximate cause of this increase lies in the fact, that an *additional* portion of the sum of the mineral substances in the field has been thereby rendered capable of assimilation by plants, and therefore become active. Without the presence of such an excess of mineral matter, the salts of ammonia, and Chili-saltpetre, would not have been attended with any effect.

A field, which, by manuring with these last-named salts, has produced a larger crop for one or more years is thereby impaired in fertility for future crops: for it could retain the same degree of fertility only when the conditions of fertility remain the same; just as it can become more fertile only by having those conditions of fertility increased. But, in the rich crops obtained by the use of ammonia salts and Chili-saltpetre, the farmer removes from his field in the form of corn and straw, the mineral constituents of the soil, and the field is consequently less rich in these substances after the harvest than it was before.

Experience teaches, that the produce of fields in the same district is very unequal, even though they contain the same quantity of decaying organic matter and nitrogen. From one meadow is obtained twice or thrice more hay than from a similar extent of another meadow placed in the same external conditions. An acre of clover land yields three or four times as much clover hay as an acre of another field.

The causes of this unequal productiveness, are always and everywhere the same.

The atmosphere conveys to two fields of equal surface a like quantity of carbonic acid and ammonia; the more fertile field, nevertheless, yields two, three, or four times more carbon and nitrogen, in the form of hay or clover, than the other. It is evident, that in such a case, the cause of the increase lies in the soil, and not in the air. The more fertile field has furnished to the plants two, three, or four times more mineral food than the other: it contained a larger absolute quantity, or a larger available proportion of these substances.

If we take two clover fields or meadows of unequal productiveness, in one of which there is accordingly present a larger quantity of mineral substances than in the other; and if we suppose that the atmosphere supplies them in one year with two, three, or four times the amount of ammonia they usually receive, and that their produce is thereby increased,—it will be found that the increase of crop in the two fields will be always unequal. The return from the more fertile field will always be greater than that from the less fertile, and this in the same unvarying proportion; for there has been no change in the sum of the conditions of fertility in the soils of the two fields.

The increase in the fertility of a field by the application of ammonia, or its salts, necessarily presupposes the presence of the conditions of this increase, and that a greater quantity of mineral matter has in a given time become active and capable of absorption.

In every case the *produce* of a field and the *duration* of its fertility bear a fixed relation to the sum of the mineral substances in the soil.

The greater or less abundance of the crop is proportional to the rapidity of the action of the mineral matters in a given time; that is, to that portion of their total quantity which is annually transferred from the soil to the plant. Hence, if a field contains so much mineral matter that, without any supply whatever, it can yield in 100 years exactly 100 average (*i. e.* remunerative) crops of wheat, it may after this time possibly be still rich enough for another kind of crop; but, in an agricultural sense, it is no longer a wheat field.

If, by a more thorough mechanical preparation of the ground, or by chemical means, such as Chili-saltpetre, common salt, and salts of ammonia, the action of the available mineral food be accelerated, the field will perhaps yield in 50 years as much grain and straw as it would have done in 100 years without these means, and in *half the time* it would be exhausted for the cultivation of wheat.

By the use of such means the *total* produce of the field is not increased, but only the quantity obtained in a given *time*.

When the agriculturist loses sight of the conditions which determine the duration of his large crops, and relies on the effect of his labour, and on the application of Chili-saltpetre, salts of ammonia, and common salt, without at the same time taking care to replace the mineral substances removed by his crops, he is then speculating on the wealth of his field, of the extent of which he knows nothing, and can receive no information from others. He seizes beforehand on the produce of his fields, which in after years would undoubtedly have come to him; and the only difference between him and a railway speculator is in general this: that the punishment for his foolish deeds inevitably overtakes him or his successors, which the speculator sometimes escapes by laying on the shoulders of others. The apparently remunerative employment of these means on many fields may last for a long time ere the agriculturist becomes aware of the injury he is doing himself by neglecting to return the mineral substances removed by his crops; but the longer he continues by them to obtain these large crops, he is approaching nearer and nearer the limits at which they must cease.

LETTER VI.

The amount of Carbonic Acid and Ammonia in the Air—The Balance of Organic Life—The Absorption and Assimilation of Food differs in Perennial and in Annual Plants—The mode of Growth of Perennial, Annual, and Meadow Plants—The quantity of Nitrogen in different Crops. —Advantage of Nitrogenous Manures to Cereals is not in consequence of the failure of Nitrogen from Natural Sources—Organic and Nitrogenous Manures useful in Annual Plants with small absorbent Leaf and Root-surface—Effect of Nitrogenous Manures less marked in plants with large Leaf-surface—Supply of Ammonia in Manure not necessary to all Plants—Green Crops condense Ammonia from Natural Sources, and supply it in the excrement of animals to Corn-fields—The Nitrogen of Manures is thus indirectly obtained from the Air—The total quantity of Nitrogen from a manured Corn-field is not greater than from an unmanured meadow, but more time is required by the latter to collect it —Explanation of the good effect of Nitrogenised Manures on Annual Plants with small Leaf and Root-surface.

THE quantity of nourishment in the air, compared with its mass, is very small.

If all the carbonic acid and ammonia dispersed throughout the atmosphere were collected in one stratum around the earth, and possessed the same density as at the surface of the sea, the layer of carbonic acid would be a little more than eight feet high, and that of the ammonia less than a quarter of an inch. Both are absorbed by plants, and the quantity of these gases in the atmosphere consequently diminishes.

Were the whole surface of the earth a continuous meadow, from each hectare (2½ acres) of which 100 cwt. of hay was yearly reaped, these meadow plants would in twenty-one to twenty-two years exhaust the whole of the carbonic acid in the air, and the whole living creation would at the same time come to an end. The air would no longer support plants—that is, would no longer furnish them with an indispensable condition of life.

We know that careful provision is made for the continuous duration of organic life. Men and animals live on plants. All organised beings have only a passing and comparatively short existence. In the vital processes of animals, the food which nourishes them is transformed into its original form ; and the same change takes place with the bodies of all animals and plants after death: their combustible elements reassume the form of carbonic acid and ammonia. Both of these substances are gaseous, and return to the atmospheric sea, to serve once more for the formation and development of a new generation.

We thus see that the duration of organic life, in reference to the combustible elements forming the frame of plants and animals, is most intimately connected with the return of these conditions. The perpetual round of changes which the Creator has traced out for them, may, to a limited extent, be influenced by man, but it goes on without him.

Wherever food in the form of corn and other produce of the soil abounds, there, men and animals will be found to consume it; and these, in fulfilling the urgent natural law of self-preservation, continuously reconvert the food that supports them into its original elements.

The atmosphere is never at rest: even in the absence of every breeze, it is in continual ascending and descending motion. The food which it gives up to plants at one spot is immediately replaced from another,—from ever flowing sources.

There is a marked difference between perennial and annual plants as regards the absorption and assimilation of food. For though different species may possess the same capacity in this respect, yet the quantity necessary in a given time for their vital purposes is very unequal. To attain a maximum of growth in the shorter period of its existence, the annual plant requires more than the biennial, and the latter more than the perennial.

Everything that tends to promote the growth of plants in general, exerts the same favorable influence on perennial plants as on biennials and annuals, but with this distinction, that the development of the former is not in the same degree dependent on accidental and passing states of weather. If the weather is unfavourable, the growth of the perennial is only retarded for a time: they can await a favourable change. Whilst thus waiting their increase is only for the time being arrested, but the annual plants reach the limit of their existence and die.

In the first periods of the growth of perennial plants, the most powerful efforts of their vital energy are chiefly directed to the formation of roots. The atmospheric food received by the leaves is destined for the prolongation and ramification of these underground organs of absorption. This fact is most distinctly perceptible in young trees, which appear to grow so slowly in the first periods of their existence, and afterwards so rapidly. When the roots have acquired a certain compass, their stem or stalk then increases in strength much more rapidly than at first, and the branches, shoots, and leaves, augment in number.

In the growth of annual plants, the food is expended in two directions at the same time, viz., for the formation of the shoots, as well as of the leaves and roots; they are, therefore, in reference to the equal supply and the proper proportion of their food, much more dependent than perennial plants on the condition of the soil, and on weather. The development of all parts of the annual plant must take place within a certain definite, relatively short period of time, and its growth can only be complete when the external conditions are equally favourable with those of the soil.

The formation of underground suckers appears to be of the greatest importance to vegetation in the case of the perennial grass and meadow plants, because by them vegetation is maintained. They appear mostly in cases where scarcity of food or external disturbing circumstances would endanger annual plants. Only the smallest portion of the plants on a thickly-covered plot of grass produces stems; the greater part develops only tufts of leaves; and a number only underground suckers. A landscape essentially derives its character from perennial plants, which everywhere take possession of the ground when not prevented by man. Cleared forest-land produces immediately in the succeeding year plants, many of which (as for example, the raspberry) flower and bear fruit in the same year, and therefore could not have grown from seed. By continuously putting forth underground suckers, plants are kept for a number of years at a low state of growth, till ultimately the conditions for their complete development recur.

The duration of vegetation on our meadows depends on this circumstance. The certainty of their produce under varying conditions of soil and weather, arises from the great number of plants, which are able to maintain themselves at this low stage of development.

Whilst one species of plants grows, flowers, and bears seed above ground, a second and third collects below it the conditions for a similar future growth. The one seems to disappear, in making room for a second or third, until the conditions for its own growth again recur. By manuring with ashes we cause clover plants to shoot out from the green sward. An abundant crop of French rye-grass showed itself when superphosphate of lime was applied, but not a straw of this grass was to be seen where no superphosphate fell.

A wonderful provision of nature ensures, by this sequence and change, the continued existence of plants, which clothe the fields with perennial green. The agriculturist, in adopting the rotation of crops in the cultivation of the annual plants which supply the food of man and animals, but follows in this operation a higher law.

The circle from which a perennial plant extracts its food enlarges from year to year; if its roots find but little in one spot, its wants are supplied from another which is richer. Whilst the roots of annual plants die every year, perennial plants preserve theirs in a state of readiness to absorb food at every favourable opportunity. Many retain their stalks or stems, in which are stored up, for the future necessities of leaves and buds, the unconsumed portion of their food. Hence, perennial plants grow with luxuriance on comparatively poor ground, which will not yield annual plants without a supply of food from the hand of man.

Annual plants cannot follow each other continuously on the same soil without exhausting it; hence, in the rotation of crops, perennial plants come most advantageously after the annual, and *vice versâ*.

The nearer an annual plant approaches in its comportment to a perennial, the more independent is it of any supply of atmospheric food. So long as a plant puts forth fresh leaves, it exists and maintains its power of absorbing carbonic acid and ammonia from the atmosphere; and, during the continuance of this power, there is so much the less necessity for a supply of these substances from the soil.

A pea plant which pushes out fresh leaves and blossoms, at the same time that its seeds are ripening, receives more combustible elements from the atmosphere, than a corn plant, whose leaves and green stem fade after the appearance of the flower, and with the ripening of the seeds, and consequently lose their power to absorb atmospheric food.

Hence we can understand why organic substances which, in decaying, supply to the roots carbonic acid and ammonia, when applied at the proper time cause in one plant an increase of vegetable matter, and in the amount of seed, whilst the produce of another is scarcely increased by them.

From an equal surface of land we obtain in different cultivated plants a very unequal amount of blood and flesh constituents, or nitrogen. If we designate by the number 100 the quantity of nitrogen which is yielded by a field of rye in the form of grain and straw, we shall obtain from the same field—

In Oats	114
Wheat	118
Peas	270
Clover	390
Turnips	470

Accordingly peas, beans, and green crops, in cultivation, yield more nitrogen than the cereals. Peas and beans give more than double, clover and turnips three or four times more flesh and blood constituents than wheat. Clover and turnips can yield on many fields this higher produce without receiving any nitrogen in manure. In the case of clover, the yield can be still further augmented by the application of ashes, and in that of turnips by superphosphate of lime.

In cultivation, nitrogenous manures prove particularly useful for cereals, though the growth of clover and root-plants on many fields is also greatly promoted by them. In general, the luxuriant growth of green crops on fields which have received no nitrogenous manure shows, that the utility or necessity of these manures for cereals does not arise from a deficiency in the supply of nitrogen from natural sources, and cannot be explained by a supposed failure of this supply. The column of air floating above a clover and corn field offers to both plants the same amount of carbonic acid and ammonia, yet from the same soil from which the agriculturist has received a very poor return of nitrogen in the form of grain and straw, he obtains three or four times the quantity of nitrogenous constituents in a crop of a fodder plant. The same source of nitrogen was open to both plants; there could, therefore, have been no deficient supply to the corn plant, since the clover drew from it its three and fourfold quantity. It is quite certain that a soil, from which a poor crop of corn has been reaped, will not be made to yield a greater quantity, even by the most abundant application of ammonia.

The failure of the corn crop must therefore be owing to other circumstances, and the proximate causes must be sought for in the condition of the soil.

On the other hand, it cannot be doubted, that two fields containing equal quantities of the fixed food of plants, are nevertheless unequally productive in cereals, if in one of them there exist more carbonaceous and nitrogenised organic matter than in the other. The field which is richer in organic matter produces a higher crop of corn and straw. It is further certain that, if an equal quantity of the fixed constituents of food has been supplied in manure to two fields, but one of them has at the same time received in addition in organic matters a store of carbonic acid and ammonia, in general the latter will produce a larger crop of corn than the other.

This increase of produce under these circumstances (in which the soil is supposed to be rich enough in mineral food and in carbonaceous and nitrogenous organic matter) takes place in the case of cereals as well as of other annual plants, with a scanty supply of leaves and limited ramification of roots; and the reason of the utility, in such cases, of organic and nitrogenised substances, is very evident. It lies manifestly in this, that the amount of nitrogenised products, which can be obtained from a given surface of such land, is in fixed proportion to the extent of *leaf surface*, or in general terms, to the organs of absorption, and to the *time* in which these organs are in a state of activity.

If one plant possesses twice the extent of surface of leaves which exists in another, it will, during the same period of vegetation, extract double the quantity of nitrogen from the air.

Of two plants with equal extent of surface of leaves, and under similar circumstances, but with unequal periods of vegetation, one will yield a larger crop than the other, if with the same supply of food it has longer time for its absorption. By manuring his fields with nitrogenous substances, the agriculturist exercises an immediate influence on the produce; and the effect of these manures, through the nitrogen they contain, is in inverse proportion to the absorbing leaf and root-surface, and to the period of vegetation of the crop.

The effect of nitrogenous manures is less marked in plants with a large surface of leaves (as in peas, turnips), or which have a longer period of vegetation (as in meadow plants, clover) than in culmiferous plants. Ammonia is necessary as food to all plants, but a supply of it in manure is, in the agricultural sense, not useful to all cultivated plants.

Experience has taught the agriculturist to make a distinction in this respect. As a rule, he does not manure his clover field with nitrogenous matters, because the crop of clover is generally not thereby visibly increased, or only very slightly; whilst he reaps a decided advantage in the increase of his produce by applying these matters to his corn fields.

The agriculturist therefore makes use of green crops as a means of increasing the productiveness of his corn fields.

Green crops, which thrive without nitrogenous manures, collect from the soil and condense from the atmosphere, in the form of blood and flesh constituents, the ammonia supplied from these sources. When the agriculturist feeds his cattle, sheep, and horses with these green crops, he obtains in their solid and liquid excrements the nitrogen of the fodder in the form of ammonia and highly nitrogenised products, and thereby a supply of manure for his corn fields.

The ultimate source of the nitrogen with which the agriculturist manures his corn fields is invariably the air. Each year he carries away from his land a certain quantity of nitrogen in the form of fattened animals, corn, cheese, or milk: but his trading capital of nitrogen is maintained and increased, if he knows how to replace the deficiency by the cultivation of green crops in proper proportions.

In the temperate zones, it is usually on the annual plants that man depends for his food; and the problem which the agriculturist has to solve, is to obtain from his land in the form of annual plants as much food for man, as perennial plants furnish to animals from the same extent of surface. Nature takes care of animals which cannot take care of themselves; whilst for the purpose of ensuring the means of his subsistence, man has been endowed with the power of making the laws of nature minister to his wants.

The best corn field, which has been manured, produces altogether no more blood and flesh constituents than a good meadow, which has received no nitrogenous manure. But the corn field without manure would have yielded a smaller amount of these constituents than the meadow.

Whatever deficiency there is in the quantity of atmospheric food, taken up by corn plants within a given time from natural sources, to produce a maximum of corn and straw; whatever amount of food the scanty supply of leaves has not the power of absorbing from the air during the short period of their existence, that portion the agriculturist supplies through the roots.

The agriculturist thus supplements by manures the difference between the amount of atmospheric food taken up in eight months by meadow plants, and that obtained by cultivated plants from the air during their more limited period of vegetation of four to six months; and he thereby ensures to corn plants, during their shorter existence, as much nitrogen for assimilation as is furnished to meadow plants from natural sources.

Hence the explanation which can be offered of the effect of nitrogenised manures and their advantages in certain cases is, that the agriculturist furnishes to certain plants, having a scanty supply of leaves and roots and a short existence, in *quantity* as manure, the nitrogen which they have not *time* to absorb from natural sources.

But the agriculturist does not always apply the nitrogen with which he augments his crops in the form of the ammonia of rotting excrements of man and animals. He also employs frequently for this purpose other nitrogenous substances, as horn, dried blood, fresh bones, rape-dust, &c.

We know that these substances, as well as all nitrogenous matters derived from man and animals, by degrees decay in the soil, and their nitrogen is gradually transformed into nitric acid and ammonia, and that the latter is absorbed and retained by the soil.

In all cases in which ammonia as such produces favourable results on crops, these substances, so far as regards the nitrogen they contain, also act in the same manner. But their effect is more slowly produced, because they require, according to the greater or less facility with which they are decomposed in the soil, a certain time for the transformation of their nitrogen into ammonia. Dried blood and flesh, as well as the nitrogenous constituents of rape-cake, act more quickly than the gelatine of bones, and the latter more quickly than horn.

LETTER VII.

Salts of Ammonia increase the number of Roots and Leaves in the first period of the Growth of Plants ; hence the superior action of these salts in Spring—Circumstances which modify the production of Leaves, Flowers, and Roots—Circumstances under which Nitrogenous and Concentrated Manures are useful—Causes of the failure of plants continuously grown on the same Soil—Food of plants when too concentrated often exerts a deleterious Chemical action—Provision in the Soil to prevent this action—Properties of Soils altered in cultivation by the removal of Mineral Matters from them, and by the increase of Organic Matters in them—The increase of Organic Matter frequently a cause of Disease—Finger and Toe disease ; its cure—Excess of soluble Silica and of hurtful Organic Matter in soils removed by Lime—Noxious Organic Matters arising from the continuous growth of Perennial Plants on Meadows removed by Irrigation.

THE experiments of Kuhlmann, Schattenmann, and Lawes, agree in showing, that the salts of ammonia exert a most favourable influence on the evolution of straw and leaves; and if this influence extends in like manner to the underground organs, the roots, then it ought to follow that the action of ammonia promotes the development of those organs destined for the absorption of food, and that these salts applied at the proper time increase the number of the leaves and roots.

This circumstance explains the favourable action exercised in spring by ammoniacal manures, whilst in summer their influence under otherwise similar circumstances is but trifling.

If the plant, in fact, has produced during the first period of its growth a sufficient number of leaves and roots, an additional supply of ammonia can be of no great use to its further development, where the other constituents of food in the soil are not deficient; for the leaves can now receive from the air the nitrogenous food necessary to the formation of seeds. In summer there is more watery vapour in the air than in the colder spring; and as the quantity of ammonia in the air, according to the observations of all experimenters, increases with the temperature and moisture, plants must necessarily find more ammonia in the air in summer than in spring. We may as a rule hold, that in the colder seasons of the year, plants are more dependent on a supply of ammonia from the soil, than in the warmer; or in other words, that the employment of nitrogenous manures in spring is most advantageous to plants.

In England and Scotland it is the result of general experience, that the earthy phosphates are not always sufficient for a good and certain crop of turnips. When sown in May they require the addition of a nitrogenous manure, whilst, if this take place in the middle of June, they thrive generally as well with phosphates alone, as when combined with ammonia.

We can hence tolerably well define the cases in which ammonia is hurtful; for whilst nitrogenous manures promote the growth of the leafy cabbage, they impede that of the roots of turnips. The latter plant is frequently observed to shoot out only stem and leaves when growing on spots upon which manure heaps have lain. Mangold-wurzel in a similar case produces the largest roots. The flowering time of these plants is delayed by this manure.

To produce flower and seeds, it appears to be a necessary condition, in many cases, that the activity of the leaves and roots should reach a certain limit,—a period of rest. It is only from this period that the vegetative activity appears to take a decidedly new direction, and that the sap, when no longer required for the production of new leaves and roots, is applied to the formation of flower and seed.

With many plants want of rain, and of the consequent supply of food, limits the formation of leaves, and promotes the production of flowers. Dry and cool weather hastens the formation of seeds. In warm and moist climates, the cereals when sown in summer bear little or no seed ; and root crops flower and bear seed more readily on a soil poor in ammonia, than on one rich in this substance.

In the employment of nitrogenous manure, the agriculturist must consequently have distinctly before him the object which he wishes to attain. He must act with plants as with animals. When he wishes to fatten the latter, and at the same time to preserve their health, he gives them daily no more food than they can digest.

Manures must always be of such a nature as to furnish plants with their suitable food at each period of their growth. Plants which have a longer period of vegetation, require consequently no supply, or, at least, a much smaller one of nitrogenous manures than those whose period of existence is short. For such as possess the shortest period of vegetation, and which grow rapidly and with vigour, the concentrated manures are preferable to those which give up their active constituents only slowly. In dry localities, winter wheat thrives after clover without further manuring; whilst, as a rule, the application of Peruvian guano or Chili-saltpetre (top dressing) is most beneficial to wheat sown in spring.

The continuous cultivation of the same plant on the same field, does not necessarily unfit this field for its production, if it is amply provided with the chemical conditions for the growth of the plant, and possesses physical properties of a right kind. If, after the third or fourth year, the plant no longer thrives on such a field, the reason manifestly does not lie in any deficiency of its vital conditions (for we have assumed that these are present), but in the accumulation of causes which injure its healthy growth.

The food of plants consists of chemical compounds, which, in virtue of their chemical properties, produce certain effects on the substance of the cells and the most delicate portions of the frame of the leaves and roots, by which plants appropriate their food. Their chemical action increases with their quantity; and if presented to plants beyond certain limits, they sicken and ultimately die.

In air in which free ammonia is present in excess, even though it be to only a most minute extent, many plants die as if struck with a poisonous blast. Carbonic acid acts in a similar way, though in a less degree; and weak solutions of free alkalies or alkaline earths and their salts in a soil produce the same effect on other plants.

In nature we find a wonderful provision exists in the chemical and physical properties inherent in the soil, for completely obviating the chemical action of the nutritive matters on the absorbent rootlets. Free ammonia, the free alkalies, and alkaline earths, are fixed by the soil, and with their loss of solubility they also lose those chemical properties which are hurtful to plants. Plants can then select what is necessary to their existence, without any hindrance from extraneous influences which may endanger their proper growth.

It is evident that the soil must possess such a neutral chemical character as the most important condition of the healthy structure and functions of the roots. The different species of plants require, however, special conditions for the growth of each. One species requires the constituents of fresh spring water; another flourishes only in bogs; others in carbonaceous and sour soils; others, again, only in ground which abounds in alkaline earths.

By cultivation the character of the soil is modified, not only by the removal in crops of a portion of its active ingredients, but also by the addition to it, by means of many plants, of a greater amount of carbon and nitrogen substances, in the form of the remains of roots. The enrichment of the soil in organic matter appears to be a cause of disease and death to many plants. Clover and many of the turnip tribe will no longer grow on such a soil, and several species of grass quickly disappear from it.

It has been frequently found in England that turnips, when grown on the same field at too short intervals, become subject to a peculiar disease, which manifests itself in an unusual development of the roots. Instead of a round, fleshy head, weighing several pounds, from which filamentous roots spread out into the ground, the tap-root splits into a great number of hard, woody, stem-like roots of the thickness of the finger (finger and toe disease). This disease, which is owing to the peculiar character of the ground, is removed by a large dose of quick lime. It is certain, however, that the lime does not act in this case, because there was previously a deficiency of it in the soil, for a supply of it to the field at seed time, like other manures, produces no effect, for the latter is apparent only after one or two years. To produce a favourable change in the quality of the field, the lime must manifestly penetrate to a certain depth, and this requires a considerable time. By the simple application of superphosphate of lime, to the complete exclusion of organic manures, Lawes succeeded in raising nine successive crops of turnips on the same land, and in the ninth year obtained 187 cwt. of roots per acre.

Rain water, in slowly filtering through a soil rich in organic matter, extracts a substance which communicates a brown colour, and at times an acid reaction to the water. An addition of burnt lime to this soil destroys the solubility of the organic matter in water, and its power of diffusion in the soil. The lime decomposes the organic substances, and by its presence converts the process of putrefaction, which is hurtful to plants, into one of decay which is advantageous to them.

The presence of organic matter in a soil rich in silicates, enables water in percolating through the soil to dissolve a much larger quantity of hydrated silicic acid than is conducive, in many plants, to the process of absorption taking place in the roots. Lime destroys this property, and, by its direct action on the silicate, potash is ultimately set free, and rendered fit for distribution in the soil. Sainfoin continues to flourish on fields rich in lime. It is certain that the presence of the lime in such a soil is not advantageous to this plant, because it requires more lime for its vital purposes than other plants which flourish luxuriantly on land much poorer in lime; but the cause for the necessity of this excess of lime must be sought for in the fact, that it destroys certain injurious matters which gradually accumulate by the continuous growth of this plant on the same soil.

As a matter of course we understand, that, in a number of cases in which the same plant will no longer grow on the same soil, the cause just indicated is not alone in operation, but deficiency of food generally, or in the proper proportions, must be regarded as the proximate cause of the failure. The necessity for taking into consideration so many causes which impede or promote the growth of plants, makes the practice of agriculture one of the most difficult of pursuits.

In fields bearing perennial plants, with roots which penetrate to no great depth, similar injurious matters gradually collect, which are hurtful to the growth of future generations of plants. The irrigation of meadows appears to accomplish the important object among others of removing these injurious matters by the oxygen and by the carbonic acid dissolved in the water, which penetrates the ground, and brings it into a condition similar to that produced by careful ploughing. An analysis of the water flowing from the meadow would probably show that it removes as much mineral matter and ammonia as it brings to it. We do not, of course, here speak of meadows to which liquid manure has been applied, or which have been irrigated with rich sewerage water from towns; for in these cases two causes are in operation to augment the produce, one of which (a supply of mineral food and ammonia) is almost excluded in the case of spring and river water.

LETTER VIII.

The food of Land Plants is not absorbed by the roots from Solution, but from the Soil directly in contact with them—Hence the necessity for a uniform distribution of the food of plants in the soil, and for the great Ramification of their Roots—A field with much mineral food may be comparatively unproductive if it is not thoroughly mixed with the Soil—The roots of a crop diminish the mineral food in those portions of the soil in contact with them—Fertility is restored to those portions by ploughing and other mechanical means, which mix the soil and allow the roots to ramify freely—Reason of the value of Green Manures—Estimation of amount of mineral food in the soil to produce different Remunerative Crops—Law of Exhaustion in soils for different crops—Action of organic remains in the soil on the mineral constituents—Progress of diminution in Grain and Straw of cultivated crops, when the Ash Constituents are not restored to the soil, and when those of the straw alone are returned—Relation between the production of Leaves and of Grain—Relative proportions of mineral food required for Grain and for Root or Leaf-producing crops—The increase of Organic Matter and Nitrogen in the soil by Green Crops, without the addition of mineral food, augments the produce of grain, but hastens the period of Exhaustion of the soil—Progress of the exhaustion of a soil by the cultivation of shallow and of deep rooting plants—The manner in which the Subsoil contributes to the prolongation of the fertility of land—Importance of the formation of large roots after germination—Exhausted fields in an agricultural sense—Fertility restored by manures—The nature of Manures—The part played by the Organic and Inorganic Matter of Manures—Farm-yard Manure.

THE culmiferous, turnip, and tuberous plants which the agriculturist cultivates, comport themselves in a most peculiar manner in the absorption of their mineral food. Whilst sea-plants receive their whole supply of these substances in a state of solution from the surrounding medium, the water which percolates through cultivated soils, brings to the roots of land plants none of the three most important and most essential elements of food, viz., phosphoric acid, potash, and ammonia. Water alone withdraws from the soil none of these substances; their passing into the organism of plants must therefore be directly effected by the organs of absorption in the ground, with the co-operation of water. The roots extract these substances from those portions of the soil, penetrated with water, which are in direct contact with their absorbent surfaces; and such portions of soil must contain the whole quantity necessary for the complete development of the plant, since the roots can receive none of them, except from the particles of earth with which they are directly in contact.

If the food of plants in the soil cannot move towards the roots, it is evident that the roots must spread about to look for food.

Plants cannot obtain from the soil more food than it contains. Further, its fertility is not to be measured by the whole quantity present in it, but only by that portion of the whole quantity which exists in the smallest particles of the soil. For it is only with such portions that the rootlets can come into close contact.

A piece of bone weighing about 30,000 milligrammes, (one ounce) in a cubic foot of earth, produces no marked effect on its fertility. But if these 30,000 milligrammes of phosphate of lime be uniformly distributed throughout the earth, it will suffice for the nourishment of 120 wheat plants. Ten thousand milligrammes of food, having a surface extent of 100 square millimètres, are within the same given time not more effective than ten milligrammes having the same surface extent. Of two fields with the same amount of food, one may be very fertile, and the other equally unfruitful, if the food is more uniformly distributed throughout the former than the latter.

The common plough breaks and turns up the soil without mixing it; it only displaces, to a certain extent, the spots on which plants have already grown. But the spade breaks, turns, and mixes it thoroughly.

A potato, turnip, or wheat plant cannot thrive on the spot in which the same kind of plant has grown in the preceding year, if the portions of soil with which the rootlets were in contact, contain no more, or only an insufficient residue of food. The roots of the succeeding plants find in all these spots either no food or only a deficient supply. Every other spot contains more.

As the smallest portions of food cannot of themselves leave the spot in which they are held firmly fixed by the soil, we can understand what immense influence must be exerted on its fertility by its careful mechanical division and thorough intermixture.

This is the greatest of all the difficulties which the agriculturist has to overcome.

If a field is to produce a crop, corresponding to the *full* amount of food present in it, the first and most important condition for its accomplishment is, that its physical state be such as to permit even the finest rootlets to reach the spots where the food is to be found. The extension of the roots in every direction must not be obstructed by the cohesion of the soil. Plants with thin delicate roots cannot grow on a tenacious heavy soil, even with abundance of mineral food. These facts explain in a very simple manner, one of the many favourable effects of green manures on such soils, and enable us to understand the reasons of the preference given in many cases, by agriculturists, to fresh over rotten farm-yard manure. The mechanical condition of the ground is, in fact, remarkably altered by the ploughing in of plants and their remains. A tenacious soil loses thereby its cohesion; it becomes brittle, and more readily pulverised than by the most careful ploughing; and, in a sandy soil, a certain coherence is introduced among its shifting particles. Each stem of the green-manure plants ploughed in opens up by its decay a road by which the delicate rootlets of the wheat plant ramify in all directions to seek their food. With the exception of their combustible elements, the ground receives from the green manure plants nothing which it did not previously contain; and these of themselves would have no effect on the increase of the crop, without the presence in the soil of the necessary mineral food.

None of the three most important constituents of food exists, by itself, in a soluble form in the ground, and none of the means employed by the agriculturist to make them available to his plants, deprives the soil of its power of retaining them; or, if dissolved, of withdrawing them from this solution. The principal end gained by the means he employs is only an uniform distribution of the food throughout the soil, so as to put it within the reach of the roots of his plants.

A $2\frac{1}{2}$ acre field (= 1 million square decimètres) of good wheat soil produces an average crop of 2000 kilo. (= 4411 lbs.) of grain, and 5000 kilo. (= 11,028 lbs.) of straw; the two contain together 250 kilo. (= 551 lbs.) of mineral substances. Each square decimètre (= 10,000 square millimètres or 15·5 square inches) of this field yields 250 milligrammes (= 3·85 grains) of ash constituents to the plants growing upon it. Each square millimètre (= ·00155 square inch), from the surface downwards, must contain a quantity of food corresponding to the wants of each individual rootlet. If the food is wanting in any one particular particle of the soil, then this portion cannot contribute to the nourishment of the plant. *The amount of food in each portion of a transverse section of ground, in each square millimètre from the surface downwards, is the measure of its capacity for production.* Each rootlet absorbs, according to its diameter, the food with which it comes in contact on its way downwards.

If we suppose that the sectional area of the roots of the whole wheat plants which grow on a square decimètre amounts to 100 square millimètres, or that upon the same surface there exists a wheat plant with two or three stems, and with a hundred roots each of a square millimètre sectional area, then must each of these rootlets receive 2½ milligrammes of mineral food in order to supply the plant with 250 milligrammes. Each of the 10,000 square millimètres (= one square decimètre), from the surface downwards, must contain these 2½ milligrammes; which would give a total quantity of 25,000 milligrammes (= 25 grammes = 386 grains) to the square decimètre, calculated to a depth of 10 inches; or 25,000 kilo. (24½ tons), to the hectare (2½ acres), *i. e.*, somewhat more than ½ per cent. of the whole soil.

A hectare which, from the surface downwards, contains no more than 250 kilo. = 550 lbs. of mineral matter (of which 50 kilo. = 110 lbs. are potash, and 25 kilo. = 55 lbs. are phosphoric acid) would, according to this calculation, be completely unsuitable for wheat; for even though each wheat plant possessed, instead of one hundred, one thousand roots, each of the thickness of a hyacinth root, it would nevertheless not be able to receive by these more than a tenth part of its wants from the soil.

According to our assumption, which probably barely reaches the full amount really present, a hectare must contain, from the surface downwards, in order to yield an average crop of wheat, at least 5000 kilo. (= 11,000 lbs.) of potash and 2500 kilo. (= 5500 lbs.) phosphoric acid.*

* If the mineral food, so very small in proportion to the whole mass of

If an average wheat crop of 2000 kilo. (= 4400 lbs.) of grain and 5000 kilo. of straw, has removed one per cent. of the mineral food from the soil, the latter remains still productive for new wheat crops in the following years; but the amount of produce diminishes.

If the soil has by mechanical means been most carefully mixed, the wheat plants of the second year on the same field will find at each spot one per cent. less food, and the produce in corn and straw must in the same proportion be smaller. Under similar conditions of weather, temperature, and fall of rain, only 1980 kilo. (= 4356 lbs.) of grain, and 4950 kilo. (= 10,890 lbs.) of straw, will be reaped in the second year; and in each following year the crop must fall off in a fixed ratio.

If the crop of wheat removed in the first year 250 kilo. (= 550 lbs.) of mineral constituents, and a hectare ($2\frac{1}{2}$ acres) of soil to the depth of 12 inches, contained one hundred times this quantity (25,000 kilo., or $24\frac{1}{2}$ tons), there will remain in the soil at the end of thirty years of cultivation, 18,492 kilo. (= 18 tons) of food.

Whatever then may have been the variations in the amount of produce from this field, in the intervening

soil (2 grains in a cubic inch), were present in chemical combination with it, it is impossible to form an idea how it could be distributed in this state everywhere in the soil, so as to be reached by the roots. The comportment of soils of the most different kinds towards solutions of these elements, shows that they are present and fixed in a way somewhat similar to colouring matter in dyed stuffs, or in charcoal which has been used to decolorise a fluid; in these cases a very small quantity in weight is sufficient to cover an extraordinary extent of surface.

years caused by different conditions of weather, it is evident, that if there has been no replacement of the mineral matters removed, there can be obtained in the thirty-first year, under the most favourable circumstances, only $\frac{185}{250}$ = 0·74, or somewhat less than $\frac{3}{4}$ of an average crop.

If these $\frac{3}{4}$ of an average crop do not yield to the agriculturist a sufficient excess of income over expenditure, if they merely cover his expenses, then the crop is no longer *remunerative*. He considers the field to be now *exhausted* for wheat crops, although it still contains *seventy-four* times more food than an average crop yearly requires. The effect of the total quantity of mineral food in the soil has been, that in the first year each root found in those portions of the soil with which it came in contact, the requisite quantity of these substances for its complete development; and the result of the subsequent continuous crops has been, that in the thirty-first year only $\frac{3}{4}$ of this quantity is found in these portions.

A field exhausted for wheat cultivation, will produce *remunerative* crops of *rye*.

An average crop of rye (=1600 kilo., or 3520 lbs. of grain, and 3800 kilo., or 8360 lbs. of straw) extracts from the ground per hectare only 180 kilo. (= 396 lbs.) of mineral matter. Under similar circumstances, one rye plant takes up only 180 milligrammes (= 2·77 grains).

If a soil must contain 25,000 kilo. of mineral matter, in order to produce an average crop of wheat, a soil in which there are only 18,000 kilo. of the same substances, is rich enough for an average crop of rye, and will yield a number of such crops which shall be remunerative.

According to our calculation a field which is exhausted for the cultivation of wheat, still contains 18,492 kilo. of mineral matter, which in their properties are identical with those required for rye.

If we now inquire after how many years of continuous rye cultivation will the average crop fall to one of $\frac{3}{4}$ the amount, we find,—assuming that this amount is no longer remunerative,—that after 28 remunerative crops, the field will be exhausted for the cultivation of rye. The mineral matters still remaining in the ground amount, however, to 13,869 kilo. (= 13$\frac{1}{2}$ tons.)

A field on which rye can no longer be cultivated with profit, is not necessarily unsuitable for oats.

An average crop of oats (2000 kilo. of grain and 3000 kilo. of straw per hectare), withdraws from the soil 310 kilo. (= 682 lbs.) of mineral matter, being 60 kilo. (= 132 lbs.) more than a wheat crop, and 130 kilo. (= 286 lbs.) more than a rye crop.

If the absorbent root surface of the oats were the same as that of rye, then oats following rye would not be a remunerative crop; for a soil which furnishes 310 kilo. out of a stock of 13,869 kilo. for a crop of oats, loses thereby 2·23 per cent. of its amount of mineral constituents; whilst by our calculation the roots of the rye extract only one per cent. This can only happen if the root surface of the oats exceeds that of the rye 2·23 times.

According to the above, the oat crops will exhaust the soil most rapidly. After 12¾ years the return of produce must sink to ¾ of its original amount.

None of all the causes which may diminish or increase the amount of a crop, has any influence on this law of exhaustion of the soil by cultivation. When the sum of the food has reached a certain point of diminution, then the soil ceases to be productive, in an *agricultural sense*, for a cultivated plant. If by incorporating with it atmospheric food, organic materials and salts of ammonia, the produce has been augmented for a number of years, the state of exhaustion will then occur *sooner*. On the other hand, any obstacle to the free absorption of food diminishes the amount of produce, and the limits of exhaustion are consequently reached at a *later* period.

For each cultivated plant, there exists a similar law.

This state of exhaustion inevitably happens, even when there has been withdrawn from the soil by a course of crops only one of all the different mineral substances necessary for the nourishment of plants; for the one which is awanting, or exists in deficient quantity, renders all the others inefficient, or deprives them of their activity.

With each crop, each plant, or portion of a plant, taken away from a field, the soil loses a portion of the conditions of its fertility; that is, it loses the power of again producing this crop, plant, or portion of a plant, after the expiration of a number of years of cultivation. A thousand grains of corn require from the soil a thousand times as much phosphoric acid as one grain; and a thousand straws, a thousand times as much silicic acid as one straw; if, therefore, there is a deficiency of a thousandth part of the phosphoric or silicic acid in the soil, then the thousandth grain and straw will not be formed. A single corn straw removed from a corn field, makes this field bear one corn straw less.

If it is true that the mineral constituents of the culmiferous plants are indispensable for their growth, and must be supplied by the soil, if the plants are to flourish; if it is true that among these mineral matters, *potash*, *phosphoric acid*, and *silicic acid*, are not conveyed to the roots in a state of solution, then it necessarily follows that a hectare (2½ acres), containing 25,000 kilo. (=24½ tons) of the constituents of the ashes of wheat, uniformly distributed through it, and in a state quite fit for assimilation by the roots, can to a certain point yield a series of remunerative crops of different species of straw plants, without any replacement of the minerals removed in the grain and straw, if a uniform state of mixture of the soil has been maintained by careful ploughing and other suitable means. The succession of such crops is determined by this, viz., that the plant cultivated the second year shall take away from the soil less than that of the first; or that it contains a greater number of roots, or, in general, a greater absorbent root surface than the first. From the average crop of the first year, there would be a diminution of produce from year to year.

The agriculturist, to whom uniform average crops are exceptions, and varying returns caused by changing states of weather is the rule, would most probably not have noticed this constant diminution, not even though his field had in reality possessed such favourable chemical and physical conditions as to have enabled him to cultivate on it for seventy years successive crops of wheat, rye, and oats, without replacing any of the mineral matters withdrawn from it.

In favourable years, good crops approaching nearly to an average one, would have alternated with bad crops in other years, but the proportion of unfavourable to favourable crops would have constantly increased.

The greater number of European fields under cultivation does not possess the physical character which has been assumed in the case just under consideration.

In most fields all the phosphoric acid necessary for plants is not distributed in the state in which it is readily available to the roots. One portion is simply dispersed throughout it in the form of little granules of apatite only (phosphate of lime), so that even though the soil may altogether contain more than a sufficient proportion, yet in its various portions there may exist in some too much, in others too little, for the wants of plants. The mechanical preparation of the soil would displace these granules, but would not cause their thorough distribution and incorporation with it. To effect this requires the *co-operation of a chemical action.*

After each rye or oat crop there remains in the soil a considerable quantity of roots, which after one or two years entirely disappear. We know that these organic matters have undergone *decay;* that their constituents have united with oxygen; and that the carbon has formed carbonic acid, which has accumulated in the air contained in the porous soil, as analysis shows us.

When rain falls on this soil, it dissolves the carbonic acid, which thereby acquires the power of taking up phosphate of lime. This carbonic acid water does not withdraw from the soil the phosphate of lime contained in it, but wherever it meets with the granules of apatite or phosphorite, it dissolves a certain portion; for in these granules there exists no cause of resistance to the action of the water; and except the cohesion between its own particles, no other extraneous influence prevents its solubility in water.

Under these circumstances, a solution of phosphate of lime must consequently be formed, which spreads in all directions around each granule. Wherever this solution comes in contact with soil not already saturated with phosphate of lime, the soil will take up and retain a certain portion of this salt. *The portion of soil now saturated with phosphate* will oppose no further obstacle to the wider diffusion of the solution.

The same process is found to take place in the diffusion of the silicic acid and potash in the soil, when the latter contains silicates which can be decomposed by carbonic acid. There is then formed around each particle of silicate a solution of silicate of potash, the constituents of which are always again fixed, in the first place by the nearest lying, and then by the more remote portions of the soil.

A certain time is required for the distribution throughout the soil of the food in the manner above described.

If we suppose that our field had contained 25,000 kilo. of the ash-constituents of wheat, distributed in the most uniform manner through it; and in addition to this, but *unequally distributed*, five, ten, or more thousand pounds of the same food, the phosphoric acid as *apatite*, the *silicic acid* and potash as easily decomposed silicates;—if we further suppose that every two years a certain quantity of the last-named substances had been rendered soluble, and capable of distribution in the soil in the manner above mentioned, and in such proportions that the roots should have found everywhere in the soil these elements of food in the same proportions as in preceding years of cultivation—a sufficient amount, therefore, for a full average crop; then should we, under these circumstances, have obtained during a series of years *full* average crops, *if we had interposed a year of fallow between each year of cultivation.* Instead of thirty constantly-diminishing crops, we should in this case have obtained, during a period of sixty years, thirty *full* average crops, if the additional portion of minerals in the soil had proved sufficient during that time to replace everywhere the phosphoric and silicic acids, and the potash, removed annually by the crops. With the exhaustion of the additional proportion of minerals in our field, the period of diminishing crops would commence; and *the further interposition from this time of fallow years would not then exercise the slightest influence on the increase of produce.*

In the case under consideration, had the supposed additional quantity of phosphoric and silicic acids, and potash, not been *unequally* but *uniformly* distributed throughout the field, and *everywhere completely accessible* to the roots of plants, and in a state fit for absorption, then *thirty full* crops would have been reaped in thirty successive years, *without the interposition of a year of fallow.*

Let us return to our field, in which we assumed that there were 25,000 kilo. of ash-constituents of wheat, thoroughly dispersed throughout it, and in a state fit for absorption, and that it was sown each year with wheat; let us now suppose that in each crop the ears only were cut from the straw, and that the entire straw was left on the field and immediately ploughed in;

then must the loss of minerals be less in this year than before, for all the constituents of the straw and the leaves have remained in the ground; we have only removed from the field the mineral constituents of the grain.

Among the substances which the *straw* and *leaves* have obtained from the soil, are found all the constituents of the *seed*, but only in altered proportions. If we express by the number 3, the whole phosphoric acid removed by the grain and straw together, the loss would be represented by the number 2, if the straw remains in the ground. The *decrease* of produce in a field in a succeeding year bears always a definite proportion to the *loss* of mineral substances by the preceding crop. The following crop of grain will be a little larger then it would have been, had the straw not been left in the ground. The produce of straw will be nearly the same as in the preceding year, for the conditions for the formation of straw have been but slightly altered.

By thus taking *less* from the field than formerly, we thereby increase the number of remunerative crops, or in other words, the total amount of grain produced in the whole series of corn crops. A portion of the straw-constituents is converted into corn-constituents, and in this form is now removed from the soil. The period of exhaustion will *always* come, but under these circumstances it occurs at a *later* date. The conditions for the production of grain go on constantly decreasing, for the minerals removed by it have not been replaced.

This relation would still have remained the same, had the cut straw been carted about the field, or been ploughed in after serving for litter to cattle. What has been supplied to the field in this way, had been originally taken from it and cannot therefore *enrich* it. When we reflect that the combustible elements of straw are not furnished by the ground, it is clear that in leaving the straw in the ground, we really leave only the constituents of its ash. The field was thereby enabled to yield a little more than it otherwise would have done, simply because less had been taken from it.

Had we also along with the straw ploughed in the grain or its ash-constituents; or instead of the wheat grain returned to the field a corresponding quantity of another seed, rape-dust (that is, rape-seed freed from its fatty oil), which contains the same ash-constituents, the composition of the soil would have remained the same as before, and the same amount of produce would have been obtained as in the preceding year.

If after each crop, the straw is always returned in this manner to the field, the further result then is, an inequality in the composition of the active constituents of the soil.

We have assumed that our field contained the mineral matters of the whole wheat plant in the right proportions for the formation of straw, leaves and grain. By leaving the straw-constituents in the soil, whilst those of the grain were constantly removed, an increase of the former took place, when compared with the proportion of grain-constituents still remaining in the field. The field retained its productiveness for straw, but the conditions for the formation of grain decreased

The consequence of this inequality is an unequal development of the whole plant. So long as the soil contained and supplied, in the proper proportions, all the necessary mineral matters for the uniform growth of all parts of the plant, the *quality* of the seed and the proportion between straw and grain in the diminishing crops remained uniform and unaltered. But in proportion as the conditions for the formation of straw and leaves became more favourable, so did the *quality of the seed deteriorate* as its quantity diminished. The sign of this inequality in the composition of the soil, as a consequence of cultivation, is the diminution in weight of the bushel of corn. Whilst at first a certain portion of the constituents of the returned straw (phosphoric acid, potash, magnesia) was expended in the formation of grain, at a later period the reverse of this takes place, and demands are then made on the grain-constituents (phosphoric acid, potash, magnesia) for the formation of straw. We may imagine that when there exists in a field this inequality in the conditions for the formation of grain and straw, a culmiferous plant may, under conditions of temperature and weather favourable for the production of leaves, yield an enormous crop of straw with empty ears.

Vine-dressers and gardeners prune trees and vines in order to obtain larger fruit and in greater quantity, by thus limiting the formation of twigs and leaves; and in many districts, as in Lower Bavaria, it is often considered advantageous to cut down or feed off the corn when half grown. It is found that by this proceeding a larger amount and a *better* quality of grain are obtained. In tropical regions many culmiferous plants bear no seed, or but a small quantity, because the soil does not contain the proper proportion of conditions for the formation of seed and leaf.

The size of the seed in many plants, is in inverse proportion to the development of the leaf. Tobacco, poppy, and clover have proportionably smaller seeds than the culmiferous plants.

The agriculturist can influence the direction of the vegetative force only through the soil; that is, through the proportion of the elements of food which he supplies to it. *For the production of the largest crop of grain it is requisite that the soil contain a preponderating proportion of food necessary for the formation of seeds.* For *turnips, leafy* and *tuberous* plants, this condition is reversed.

An average crop of turnips with leaves contains five times, a clover or potato crop twice, as much potash as the grain and straw of a wheat crop from an equal surface. A clover and a potato crop together remove from two fields of a hectare each, as much phosphoric acid as the grain of three wheat crops from three fields of the same size.

It is therefore evident, if we cultivate potatoes and clover on our field which contains 25,000 kilo. of the mineral constituents of wheat, and remove the whole produce of tubers and clover, that we withdraw from the soil of these two fields as much phosphoric acid, and three times as much potash, as by three wheat crops. It is certain, that this removal from the soil, by another plant, of these important mineral substances, produces a great effect on its fertility for wheat; the yield and the number of the wheat crops diminish.

If, on the other hand, during a period of two years, we had cultivated on the field, wheat in the first year, and potatoes in the second, and had ploughed in the whole of the potato crop and the wheat straw, and had continued to do this for sixty years, we should not by these means have in the least degree altered or augmented the produce in grain, which the field was capable of yielding. The field has neither *acquired* nor *lost* anything by the cultivation of potatoes, for these were always left in the field. When the grain crops taken from the field have diminished the store of mineral matters to $\frac{3}{4}$ of their original quantity, then this field ceases to furnish a remunerative crop, if $\frac{3}{4}$ of an average return no longer yield any profit to the agriculturist. We arrive at the same results, if, instead of potatoes, we had interposed crops of clover, and had in the same way each year ploughed it in. We have assumed that the physical condition of the soil was most favourable, and consequently, could not be improved by incorporating with it the organic matters of the clover and potatoes. Even had we removed the potatoes from the field, mown and dried the clover, and then carted the potatoes and hay back to the field, or made them first pass through the cattle stalls, or made any other use of them; had we in this way returned to the field the whole sum of mineral matters in both crops, we should not by all these operations have produced from it in thirty, sixty, or seventy years, a single grain more than would have been obtained without all these changes. During this whole period the conditions for the production of grain have not increased, but the cause of decrease in the crops has remained the same.

The ploughing in of the potatoes and clover could produce a beneficial effect only on those fields, in which a favourable physical state did not exist; or in which the mineral matter was unequally distributed, and was partly inaccessible to the roots of plants. But an action of this kind is just the same as that of green manuring, or of one or more years of fallow.

By the incorporation with the soil of the clover and organic substances, the amount of decaying matters and of nitrogen in it is increased from year to year. All that these plants received from the atmosphere remained in the ground, but the enriching of the soil with these otherwise useful matters cannot effect the production of more grain than formerly; for this depends on the proportion of the minerals in the soil, and these have not been increased, but on the contrary, have constantly decreased, in consequence of the removal of the corn. By the increase of nitrogen, and of decaying organic matter in the soil, the produce might possibly be augmented for a number of years, but the period at which such land would no longer produce a remunerative crop, occurs in such circumstances only so much the more quickly.

If we cultivate on three different wheat fields respectively, wheat, potatoes, and clover, and plough all the potatoes and clover yielded by the other two into the wheat field, from which the grain alone is removed, we shall by these means render the latter more fertile than before, for we have enriched it by the whole amount of minerals which the potatoes and clover had extracted from the other two fields. It has received three times as much phosphoric acid, and twenty times as much potash, as the grain has carried away.

This wheat field will now be able to produce in three successive years, three full grain crops; for the conditions for the production of straw have remained unchanged, whilst those for corn have been increased threefold. If the agriculturist in this manner raises in three years as much corn as he would have done in five on the same fields, without the co-operation of the mineral constituents of the clover and potatoes, *then has his profit now evidently become greater*, for he has reaped with the seed for *three* crops as much as he would have done in the other case, with the seed for *five*. But the other two fields have lost in fertility as much as the wheat field has gained; and the final result is, that *with less cost of cultivation, and with more profit* than before, the agriculturist has in his three fields anticipated *the period of exhaustion* which would inevitably have overtaken them by the continued withdrawal in grain of the mineral constituents of the soil.

The last case that we have to consider is, when the agriculturist, instead of potatoes and clover, cultivates turnips and lucerne, which, by means of their long and deep penetrating roots, extract a large quantity of mineral matter from the subsoil, which is not reached by the greater number of the roots of the cereals. Where the fields possess a subsoil, favourable to the growth of these plants, we double, as it were, the extent of surface capable of cultivation. If the roots of these plants received the half of their mineral matters from the subsoil, and the other half from the arable soil, the latter will lose by the crops only half so much as they would have done, had the *whole* of the mineral food for these crops been obtained from the arable soil alone.

The subsoil, considered in the light of a field apart from the arable soil, thus furnishes to the turnip and lucerne crops, a certain quantity of mineral matter. If we suppose that in harvest the whole of the turnip and lucerne crops had been ploughed under in the wheat-field, which had yielded an average crop of grain, and in this way as much and more mineral matter had been returned than the grain had removed; then by these means, this wheat-field *can be maintained at the same degree of fertility at the expense of the subsoil, just so long as the latter continues productive for turnips and lucerne.*

But since turnips and lucerne require for their growth a very large quantity of mineral matter, the subsoil will be the sooner exhausted, in proportion to the smaller quantity of these substances it contains. Now, as the subsoil is not in reality separated from the arable soil, but lies beneath it, it can scarcely receive back any of the substances it has lost, because the arable soil retains that portion of them which has been added to it. It is only that part of the potash, ammonia, phosphoric, and silicic acids, which has not been taken up and fixed by the surface soil that can penetrate to the subsoil.

By the cultivation of these deep-rooting plants, superabundance of food can consequently be obtained for all those which derive their nourishment chiefly from the surface soil. This supply will not, however, be of any duration; for, in a comparatively short time, many fields will cease to produce these plants, because the subsoil is exhausted, and its fertility is only restored with difficulty. In the first place, lucerne no longer grows, and turnips are only now produced in so far as they are able to obtain their full supply of minerals from the surface soil. Potatoes, which derive their supplies from the upper layers of the surface soil, endure the longest.

The quantity of food which a plant receives from the ground is not alone dependent on the quantity which is present in the finest particles of the surface soil, but also on the number of organs which extract this food from the ground. Two roots will obtain twice as much as one.

The crop is partly dependent on the first root formation.

A grain of wheat or barley contains within itself so large a quantity of food, that it stands in no need of the soil in the first period of its growth. The seeds of these plants when simply moistened, produce ten or more rootlets from six to eight lines in length. The heavier the grain, the stronger and more vigorous is the formation of roots. The seed corn, without receiving anything from the ground, extends in all directions its organs of absorption, by which it procures its food from a comparatively great distance. Hence the agriculturist attaches great importance to the careful selection of seed.

Small seeds, such as those of tobacco, poppy, and clover, require a richer or more thoroughly prepared surface soil, to prevent the loss of a large proportion; because the soil in the immediate neighbourhood of the seed must at once supply it with food after germination. Hence, as the agriculturists say, such plants are more difficult to raise.

The seeds of the cereals may be compared to a hen's egg, which contains within itself all the necessary elements for the development of the young animal. Husbandry would certainly assume quite another form, if for every single cereal plant, as many seeds should be lost as is the case with poppies, tobacco, and even clover.

The quantity of food which a plant obtains from one and the same soil is in proportion to its absorbent root surface. Of two species of plants, which require the same quantity and a similar relation of mineral food, the one with double extent of root surface takes up double the quantity of food.

If it is true that the constituents of the ash of plants are indispensable to their life and growth, it is evident that whatever else may exert a favourable influence on their growth, must be *subordinate to the law*, that the soil, in order to be fertile in an agricultural sense for a cultivated plant, must contain the constituents of the ash in sufficient quantity, and in a state the most suitable for absorption.

The agriculturist has to do with the soil alone; it is only through it that he is able to exercise an immediate influence on plants. The attainment of all his objects in the most complete and profitable manner, pre-supposes the exact knowledge of the effective chemical conditions for the life of plants in the soil; it further pre-supposes, perfect acquaintance with the food of plants, and the source from which it is derived, as well as with the means for rendering the soil suitable for their nutrition, combined with experience and skill in employing them in the proper way, and at the right time.

It is evident from the above statement that the cultivation of plants tends to drain or to render a fertile soil unproductive. In the produce of his fields destined for the food of man and beasts, the agriculturist sends away that portion of the active ingredients of his soil which contributes to the growth of this very produce. The fertility of his fields continuously diminishes, whatever may be the plants he cultivates or the rotation he adopts. The export of his produce is nothing else than a spoliation of his soil of the conditions for its reproduction.

A field is not exhausted for corn, clover, tobacco, and turnips, so long as it still yields remunerative crops *without requiring restoration* of the minerals which are removed. *It is exhausted* from the moment that the hand of man is needed to restore to it the failing conditions of its fertility. *The great majority of our cultivated fields are in this sense exhausted.*

The life of men, of animals, and of plants, is connected in the closest manner with the return of all the conditions which promote the vital process. The soil by its constituents contributes to the life of plants; its continuous fertility is inconceivable and impossible without the return of those conditions which have rendered it productive.

The mightiest stream, which sets in motion thousands of mills and machines, fails, if the streams and brooks run dry which supply it with water; and these streams and brooks in their turn dry up, if the myriads of little drops of which they consist do not return in the form of rain to those spots from which they have their source.

A field which has lost its fertility by the successive cultivation of different plants, acquires by the application of *farm-yard manure*, the power of producing a new series of crops of the same plants.

But what is *farm-yard manure*, and whence is its origin? The land of the husbandman is the source of all this manure. Manure consists of the straw which has served for litter, of the remains of plants, and of the fluid and solid excrement of man and animals. The excrement is derived from the food.

In the bread which a man daily receives, he consumes the ash-constituents of the seeds of the cereals whose flour has served for the preparation of the bread; in flesh, the ash-constituents of flesh.

The flesh of herbivorous animals, as well as its ash-constituents, are derived from plants. These ash-constituents are identical with those of the seeds of leguminous plants; so that if a whole animal were burnt, the residual ash would not differ from that of beans, peas, and lentils.

In bread and flesh, man consequently consumes the mineral matters of seeds, or of the constituents of seeds, which the agriculturist obtains from his land in the form of flesh.

But a very small fraction of the large amount of mineral substances received by man in his food during a lifetime remains in his body. The body of an adult does not increase in weight from day to day, it therefore follows, that all the constituents of his food have passed again completely out of his body. Chemical analysis demonstrates that the ash of bread and of flesh exists in his excrement very nearly in the same quantity as in his food. The comportment of the food in his body is just the same as if it had been burnt in a furnace. The urine contains the soluble, and the fæces the insoluble mineral matters; the bad smelling ingredients are the smoke and soot of an incomplete combustion. With these are also mingled the undigested and indigestible remains of food.

The excrement of swine fed on potatoes contains the ash-constituents of potatoes; that of the horse, the mineral matters of hay and oats; that of cattle, the ash of turnips, clover, &c., which have served for their food. Farm-yard manure consists of a mixture of all these excrements together.

By farm-yard manure, the fertility of a field which has been exhausted by cultivation, is completely restored. This is a fact which the experience of thousands of years has established. In farm-yard manure the field receives a certain quantity of organic, that is, combustible matter, and the ash-constituents of the consumed food. We have now to consider what part was played by the organic and inorganic matter in this restoration of fertility.

The most superficial examination of a cultivated field shows, that all the combustible matter of plants which are reaped from the field are derived *from the air, and not from the soil.*

If the carbon of only a portion of the vegetable matter in the crop were derived from the soil, it is perfectly clear, that if the latter contained at first a certain amount of this element before the harvest, this quantity must become smaller after each crop. A soil poor in organic matter would be less productive than one in which it is abundant.

Observation, however, shows, that a field under continued cultivation does not in consequence become poorer in organic or combustible matter. The soil of a meadow, which during ten years has yielded a thousand cwt. of hay per hectare, is not, after this period, poorer, but richer in organic substances. A clover field, after a crop, retains in the roots remaining in the soil more organic matter, and more nitrogen than it originally possessed; but it has become unproductive for clover, and yields no longer a remunerative crop.

A wheat or potato field is in like manner, after a crop, not poorer than before in organic matter. *In general the soil is enriched by cultivation with combustible constituents, but its fertility nevertheless steadily diminishes.* After a number of consecutive remunerating crops of corn, turnips and clover, these plants are found to flourish no longer on the same soil.

Since, then, the presence of decaying organic matter in a soil, does not in the slightest degree retard or arrest its exhaustion by cultivation, it is impossible that an increase of these substances can restore the lost capacity for production.

In fact by incorporating with the soil of a field completely exhausted, boiled saw-dust, or salts of ammonia, or both together, we cannot restore to it the power of yielding a second or third time the same series of crops. If these substances improve the physical character of the soil, they will exercise a favourable influence on the produce; but after all, their action still consists in accelerating the exhaustion, and rendering it more complete.

Farm-yard manure, however, restores thoroughly the power of producing the same series of crops, a second, third, or a hundred times. It arrests fully, according to the quantity employed, the state of exhaustion; its application may render a field more fertile; in many cases more so than it ever has been.

The restoration of fertility by farm-yard manure cannot have been caused by the presence of combustible matters (carbonaceous and nitrogenous substances). If these produced any good effects, they were of a subordinate nature. *The action of farm-yard manure depends most undoubtedly on the amount of the incombustible ash-constituents of plants in it, and is determined by these.*

In the farm-yard manure the field received back in fact a certain quantity of all the minerals which had been withdrawn by the crops. The decrease in its fertility stood in exact relation with the *removal* and the restoration of the fertility with the *restitution* of these mineral substances.

The incombustible elements of cultivated plants do not of *themselves* return to the soil like the combustible in the atmospheric sea from which they are derived. By the hand of man alone are the conditions of the life of plants given back to the soil. By farm-yard manure, in which these conditions are fulfilled, the agriculturist, as if by a law of nature, restores to his field its lost powers of production.

A rational practice maintains the circulation of all the conditions of life; and empirical practice breaks the chain which binds man to his home, by robbing the soil of one condition after another of its fertility. Though the empiric knows that the soil is different to-day from what it was yesterday, he nevertheless believes that it will be to-morrow what it is to-day.

Founding on the experience of yesterday, he teaches that the fertile soil is *inexhaustible;* but science, guided by *laws,* shows that the productiveness even of the most fertile soil, has its end, and that the very soil which appears inexhaustible, *is exhausted.* Because nature was kind and gave abundantly to the father, the empiric thinks that the son may also take abundantly and without any care for the future. On the fact that man has a home, and that the spot of earth, from which he toils with the sweat of his brow to gain his subsistence, is his home, depends the development of the human race. The continuance of his existence in his home is dependent on the law, that *force is expended by use and maintained by supply.*

LETTER IX.

Constant relation between the Sulphur and Nitrogen of Organic Compounds and the Alkaline Phosphates and Alkaline Earths of Cereals and Leguminous plants—Mineral substances are as indispensable to the Life of Animals as to that of Plants—The amount of Phosphoric Acid and of Potash ascertained by analysis as existing in Soils is very small—The errors of Practical Teachers proved from the writings of Practical Agriculturists—Fertility of land cannot be maintained by Nitrogenous and Carbonaceous Manures alone, but by the Restoration of the Ash Constituents of Plants—Critical examination of the views of Walz, a practical teacher, on the Nutrition of Plants—The mineral food of plants in arable soils is not inexhaustible—The volatile and organic matters of Manures are not the most important—The nature of Guano and its active constituents.

THE life and development of an organic being cannot be regarded as depending on chance. The assimilation of its food, the transformation of the elements of this food into living forms, and all organic processes, we find are governed by laws of necessity and reciprocal dependence, which, like the wheels of a machine, but in an infinitely more perfect manner, play into each other, and give rise to all its vital manifestations, its existence and continuation.

Chemical analysis has shown that in the seeds of the cereals and of the leguminous plants, those sulphur and nitrogen constituents which, in the process of nutrition of men and animals, are employed in forming the combustible matters of blood, are always accompanied by alkaline phosphates and alkaline earths, and that between both there exists for each seed a fixed and unchangeable relation. Whenever the percentage of phosphoric acid increases or diminishes in any seed, we observe a like increase or diminution in the sanguigenous constituents.

Chemical analysis has further shown that, in the blood of man who consumes bread, or in that of a warm-blooded animal fed on seeds, there exist the same incombustible matters as are contained in the food. The ash-constituents of the blood of cattle, sheep, swine, correspond to the ash-constituents of the turnips, herbs, or potatoes on which these animals have subsisted.

The mineral elements of all the different parts of plants are, however, as indispensable to the life of animals, to the formation of their blood, and to its functions, as they are to the life of plants.

Phosphoric acid is a constituent of the brain and of the nerves; the alkaline phosphates and alkaline earths exist in the flesh of all animals: and a warm-blooded animal without bones (phosphate of lime), is inconceivable to us. The ash of green crops is rich in alkaline carbonates and common salt; and the blood of herbivorous animals abounds in alkaline carbonates, the chloride of sodium serving for the formation of the carbonate of soda of this fluid. Tea-leaves, of which man makes so much use in infusion, contain in their ash 17 per cent. of phosphoric acid; in mulberry-leaves, the food of the silkworm, the amount does not exceed 5 per cent. Each of these numbers has its physiological meaning.

Were it possible for a plant to grow, flower, and bear seed without the co-operation of mineral matters, it would be utterly valueless to man and animals. A dog will die of hunger in presence of a dish full of raw or boiled white and yolk of eggs, in which is awanting one of the substances most important for the formation of blood. The first trial teaches him that such food is as inefficient as a stone for the purposes of nutrition.

The constituents of the ashes of turnips and of meadow plants give them their nutritious value. Did they not exist in them, such plants would not be consumed by horses and cows.

Everywhere in nature prevail those harmonious laws, which attach life to the earth, and maintain it in perpetual freshness and duration. Only there does the earth become old, and the germ of life is extinguished, where man in his narrow-mindedness ignores and denies their existence, when he opposes the circulation of the conditions of life, and deranges and obstructs their united action.

It is certainly one of the most singular, if not one of the most inexplicable circumstances of the present day, that the existence of these natural laws is ignored by a great number of practical agriculturists,—precisely by those men who, in their occupation, are in a position to perceive daily the signs of their existence. Teachers of practical agriculture universally recognised to be the most distinguished and skilful, have for sixteen years, and even up to a recent period, endeavoured to prove that these laws have no value in connection with *fertile* soils; that the *increase of the fertility of a field by fallow and by mechanical operations, and the removal of the mineral matters of the soil in the crops, do not diminish the duration of this fertility; that the ground may retain continuously its fertility even when they neglect to supply the minerals which have been withdrawn*, that is, *to restore the original composition of the soil.* They teach that a *fertile* field contains an *inexhaustible* amount of the ash-constituents of plants, and that, consequently, deficiency of these can never occur in it; that the fertility of a soil is in exact proportion to the quantity of *combustible matters*, of *humus* and *nitrogen* in it; and that the want of fertility is owing to the want of nitrogen, and that the exhaustion of the land depends on the withdrawal of the latter. Manure, they assert, does not produce its beneficial effects by returning to the ground those elements which have been withdrawn from it in corn, clover, turnips, tobacco, flax, hemp, madder, wine, &c., but it acts by its combustible constituents, and its effect is in proportion to the amount of *nitrogen* it contains. Its incombustible elements only quietly look on to see how the other matters are doing, something in the same way as the moon does when the dew is falling.

The practical man regards with a smile of contempt the scientific proofs of his errors, but this smile does not arise from the feeling of conscious superiority which knowledge imparts, but it has its origin in a different source.

Chemical analysis has with its rigorous methods proved, that of thousands of fields there is *scarcely one* which contains more than 1 per cent. of the ash-constituents of plants, of clover for instance, in a state suitable to the wants of that plant.

In 1848 the Royal Institute of Rural Economy in Berlin caused the soil from fourteen different places of the kingdom to be submitted to chemical analysis. The specimens were taken from fields which were as much alike as possible, and a portion of each specimen handed to *three different chemists* for analysis. It resulted from these analyses that the mean quantity of phosphoric acid and potash (the latter in a state probably fit for assimilation) amounted, in five fields to $\frac{2}{10}$; in six, to $\frac{3}{10}$ up to $\frac{5}{10}$; and in three, to $\frac{5}{10}$ up to $\frac{6}{10}$ per cent.

These analyses do not teach that a soil which contains $\frac{6}{10}$ per cent, of these mineral substances is in consequence more fertile than another in which there exists only $\frac{2}{10}$ per cent.; but they show with tolerable certainty, that it contains a greater or less proportion of them.

Practice, on the other hand, asserts that every soil contains the ash-constituents of all plants in inexhaustible quantities.

Chemical analysis points out in the most positive and undoubted manner, that a crop of clover removes from the soil in its ash-constituents a number of the conditions of its fertility for this plant; it shows that, in the excrement of animals fed on clover, are contained the ash-constituents of clover, and that consequently, by the employment of such a manure, the whole of these ash-constituents which have been removed by the clover are again restored to the land.

As harmonising with the scientific doctrine, that the exhaustion of a clover field really depends on the *removal* of the *ash-constituents* of the clover, and the renewal of its fertility by *farm-yard manure*, on the *restoration* of these same mineral matters, the writings of the most experienced agriculturists show, that a field which produced no clover, can be made productive for a series of such crops by manuring with *wood-ashes*, which contain the same mineral matters as clover; that in the Netherlands this manure is of the most general application for this purpose; and that in Westphalia there is a proverb that "*he pays double who buys no ashes.*" (Schwerz, Anleitung zum prakt. Ackerbau, Bd. ii. S. 323.) It is a well-known fact that on strewing wood-ashes on a meadow, thousands of clover plants make their appearance where they were not visible before.

Chemical analysis further shows that a similar relation exists between a soil and all plants which are grown upon it; that a field which will no longer yield grain, but straw, bears a rich crop of the former if it has been manured with the ash-constituents of grain, and in many cases even with phosphate of lime alone.

In complete opposition to the modern doctrine of our agriculturists, it is proved by indisputable facts that the fertility of the soil is not increased by the amount of organic or combustible matters in it, or by the supply of these alone; that a soil which contains these in the greatest abundance is, as a rule, unproductive; and that the application on a wheat field of nitrogenous matters—such as the salts of ammonia—in many cases diminishes rather than increases the crop of grain. It has further been proved that ammonia and nitrogenous manures do not augment the produce of clover, unless accompanied by the ash-constituents of the plant; that by themselves they act favourably, only on such fields as are rich in mineral matters; and that their continued use in such cases only more completely exhausts the land—that is, makes it still more unproductive for future crops than it would have been without their action.

If our fields really contained so large a quantity of the mineral matters of plants that they could not be exhausted by cultivation; if the fertility was dependent on the presence and their exhaustion on the absence of ammonia or nitrogenous substances, then an endless series of full crops should be obtained by the supply of these alone, *without the addition of any mineral matter.* It is, however, an established and indisputable fact, that the maintenance of the fertility of our fields is *impossible* without replacing the minerals withdrawn by the crops. Hence it follows that farm-yard manure does not act by its combustible elements, and that if the latter in any case produce a favourable effect, it is only when they are accompanied by the ash-constituents of plants which have been removed by previous crops, and which are awanting in the field.

I believe that among the readers of these letters there will scarcely be found one, at all acquainted with the rules of logic, who could have any doubts of the truth of the conclusions deduced from the chemical analysis of the *soil*, of *plants* and of *farm-yard manure*. These analyses have been made in thousands by different chemists in Germany, England, and France; and all agree perfectly in their results. If indeed the existence of a fact can be ascertained by the balance, there is none in the whole domain of chemistry more firmly established than this, that even the most fertile soil contains but an extraordinarily small quantity of the ash-constituents of plants in comparison with its chemically-inactive mass. It will be sufficient to give an idea of this fact when I state that the ablest chemists failed in discovering, before 1834, potash as a constituent of soils, of clay, and of limestones, because its amount is so small; and that before the discovery of new and hitherto unknown re-agents, the simple detection in the soil of phosphoric acid (without any attempt to ascertain its quantity) was attended with the greatest difficulty. In these statements we find a justification of the views formerly held by philosophers that *potash*, *lime*, and *phosphoric* acid are products of the vital processes or of the vital force.

As is well known, there is an infinite variety in the composition of the rocks and minerals, by the disintegration of which soil is formed. There are minerals which are rich in potash, and which, like felspar, contain no lime; in others, silicic acid or magnesia is awanting, or like lime-stones, they contain only traces of alkalies. It is only in exceptional cases, and in those rocks which are not extensively distributed, that it has been possible to estimate by chemical analysis the weight of the phosphoric acid present.

Like gold in the gold districts of America and of Australia, arable soil is the residual matter of rocks shattered by mighty mechanical actions, and decomposed by chemical causes. The granite gravel in the neighbourhood of Darmstadt, in which can be detected felspar, mica, and quartz, is as unproductive as pure quartz or pounded marble. A thousand years are perhaps necessary to form from many rocks, from basalt, granite, porphyry, trachyte, &c., a layer of arable soil, a line thick, such as is seen in wide valleys and low grounds, and to give it the physical and chemical properties which render it suitable for the growth of plants.

Our modern teachers of agriculture inculcate that a fruitful soil is inexhaustible in the ash-constituents of plants, which are the essential conditions of their existence; and the present system of agriculture is, in all its relations, based on this view, and on the further supposition that the increase of the produce of the ground can only be effected, or chiefly so, by the supply of organic matters, the elements of which are obtained, not from the soil, but from the air.

Practical agriculture asserts, that in such practical questions which refer to *soils*, *crops*, and *manures*, geology and chemistry have no voice; *experience* alone can decide in such cases, and the deductions of science are not confirmed by it.

We will now examine a little more narrowly the nature of this experience, and the grounds on which she bases her teaching. If founded in truth, *it must secure the duration of the fertility of productive soils:* it must provide practical agriculturists with the means of restoring to their land the fertility lost by cultivation. If those who follow such teaching are ever in want of these means, then is its condemnation pronounced.

Since the commencement of the contest regarding the scientific principles of agriculture, many excellent agriculturists have communicated to me the most interesting proofs, from their own practice, of the truth of these principles, which they have hesitated to publish in an agricultural journal, through fear of being involved in a discussion, which, as they very modestly expressed it, they had not sufficient scientific knowledge to carry on. In the position which I occupy, I stand, as may be supposed, towards agriculturists who cultivate their own land, only in social relations of the most instructive and agreeable nature to myself; when, therefore, in these letters, I speak of practical agriculture, or practical agriculturists, as a matter of course only literary practical agriculturists are meant, and those who write and lecture in support of the doctrines of the school to which they belong. Among our agriculturists are to be found many men of the greatest intelligence and information, who, like the gentleman, general, lawgiver, and consul of Rome's best age, follow, from inclination, agriculture as the noblest occupation, and manage their own estates. No one can reasonably expect that such men are to account for views and doctrines which are not theirs, but which they have adopted as they were taught.

A totally different relation, however, exists between science and the writers on practical agriculture, whose competence to pronounce an opinion on the present important questions may not be disputed. From such men it must absolutely be required that they bring to the discussion of such questions, so much of the rudiments at least of chemistry, physics, and geology, as are usually taught in ordinary schools, so that no doubts may be raised as to their intellectual capacity to comprehend correctly the questions at issue.

The simple statement of the views and doctrines from his last work, of one of the ablest and most influential teachers of agriculture, as to the composition of the soil, the causes of its fertility and exhaustion, and the action of manures, will be sufficient to enable us to form an opinion on this point. This publication is expressly intended by the author to correct scientific teaching, and to bring it into harmony with practical experience.*

In the application of his theory to practice, the author of this publication puts forward as a fundamental principle that, "the soil (the surface and subsoil included), may be said to contain an inexhaustible supply of those mineral elements of food which it received at first from nature, and furnishes by disintegration to plants."—(s. 116.)

The following proposition is propounded by him, "Is the soil of a field of such a nature that it can be completely exhausted in a shorter or longer period of its soluble and insoluble mineral matter, if we do not restore to it the portion which is taken away by the crops?" and it is answered in the following way:—(s. 28.)

"The soil consists of disintegrated rocks, and either rests upon these same rocks or on others elsewhere; the transported soil may, nevertheless, have remained the same, and corresponds at least to the rocks from which it has its origin (p. 29, &c.).

"All rocks undergo disintegration, and the products when not removed remain resting upon these rocks.

* "On the Nutrition of Agricultural Plants. An Examination, in an Agricultural Point of View, of the Fifty Axioms of Baron Liebig," by Gustav Walz, Director of the Agricultural Academy at Hohenheim, Stuttgart. Cotta, 1857.

The disintegration is chiefly effected by atmospheric causes, which extend their action down to the rocks lying deep under the débris. If, then, a soil is fertile for a given class of plants, and contains the mineral food for these plants in sufficient quantity, in proper proportions, and in a state fit for assimilation, and if it still rests upon the original rocks from which it was produced, *then these underlying rocks also contain the same mineral food* as the soil and subsoil, and in the same proportions.

"If we withdraw from the soil its constituents by crops, its volume diminishes, and the rocks are thereby rendered more accessible to the action of the atmosphere. If the disintegration of the latter proceed in the same ratio as the constituents of the soil above them are withdrawn, then shall we be able to obtain crops from it without restoration of the mineral matters, until the whole quantity in the soil, and in the rocks, be consumed.

"Suppose the soil of an hectare field (2½ acres), weighs 4½ millions kilogrammes, and contains 10 per cent. of the mineral food of wheat plants in the right proportions and in a state fit for assimilation, such a field could, without any further supply, produce 1829 corn-crops. A three-crop rotation could last 2742 years without restoration of the mineral matters; and were the rocks at the commencement of the tillage already disintegrated to the depth of several feet, *as is generally the case*, then the three-crop rotation would have the prospect of enduring for each foot depth of earth other 2742 years. After this period, however, the rocks under the subsoil will again undergo further disintegration, and thus there is a prospect of continuing tillage until the rocks forming the soil are entirely disintegrated, and the mineral constituents consumed. But there comes then another class of rocks under these, &c. &c.

"By yearly removing ash-constituents from the soil, its volume is reduced. The agriculturist, however preserves a soil of the same depth by turning up an equal quantity from the subsoil. If all the mineral food in the soil has been consumed, we have lost 10 per cent., and turned up 10 per cent. from the subsoil. The turned up mass of earth, however, only contains 10 per cent. of mineral food. Hence, only $\frac{1}{10}$ of the withdrawn matters is replaced, the remaining $\frac{9}{10}$ being waste matter. The second period of the supposed three-crop rotation would therefore not last 2742 years, but only $\frac{1}{10}$ of this time, viz,, 274 years; it is only after several such periods that the field would be exhausted. *In the end there would remain nothing but insoluble silica and clay.* To maintain the fertility of this soil in mineral matters, the withdrawn ash-constituents must again be supplied to the soil, or the waste matter lying on the subsoil be removed. In this operation nature helps us by yearly washing away the soil, in proportion to its greater or less inclined position. Finally, with respect to the replacement of mineral matter in the soil, even rain, and wind also, assist in supplying them."

"Thus, the restoration required, after a shorter or longer time, of the mineral matters removed by crops, in such a soil as we have supposed above, may take place only after thousands of years; in a soil with 1 per cent. of mineral matters, after hundreds of years; and with $\frac{1}{10}$ per cent., after tens of years.

"The transported soil comports itself in a similar manner to the untransported; the rocks lying under it will likewise undergo decomposition, &c. &c."

Our teacher of practical agriculture concludes his argument with these words: "*The two axioms*, viz.,

> 1st, "The increase of the fertility of a field by fallow and mechanical operations, and the removal of the mineral substances in the crops without replacing them, are followed, after a longer or shorter period, by continued sterility;" and,
>
> 2ndly, "If the soil is to preserve permanently its fertility, the mineral matters withdrawn from it must, after a shorter or longer period, be replaced; that is, the composition of the soil must be again restored,"

these two points apply, therefore, in our time, only to soils of the very worst description, which required from the very commencement a supply of these substances." (W. S. 34.)

The above argument of one of our best teachers of practical agriculture, which professes to harmonise with his agricultural experience, might well awake, in the minds of many of our reflecting agriculturists, just doubts as to the truth of the prevailing system of agricultural teaching.

Sound common sense demands, in proof of the proposition, *that only the very worst kinds of soil require for the production of further crops, the restoration of the withdrawn mineral matters*—that numerous instances should be adduced from common agricultural experience that a fertile soil, in order to continue productive, stands actually in no need of this supply of these matters; that for ten, twenty, or a hundred years, it has annually yielded crops without any replacement whatever of the withdrawn minerals!

This proof, the only one which the writer from his point of view could adduce for refuting the results of the chemical analysis of soils, he still owes us, as well as the proper definition of his notion of a "fruitful field." It is evident, that if the term "fruitful field" includes only those fields which exist as exceptional cases in Hungary, in many parts of Russia, in low lands and valleys, and which are used as meadows, and appear to be inexhaustible because they are not yet exhausted, then the soil of ninety-nine out of every hundred fields that are called *fertile* in Bavaria, Prussia, and Saxony, belong to the *worst kinds*—a view, which no one can support.

Our teacher of practical agriculture does not pay any attention to these actual facts, but brings forward his proofs in his own peculiar way. Without telling us what he understands by rocks, soil, and subsoil, and what kinds of rock, soil, and subsoil he means, he proceeds to apply these terms as if all soils, rocks, and subsoils were identical; and leads us to believe that all soils, after their exhaustion by crops, leave, as a residue, *quartz* and *clay*. Such an assertion, however, he would not seriously make, for in that case a great part of Wurtemberg would be without any soil.

To come to an agreement in a discussion, people must understand each other; for if the one individual means by a word, sometimes one thing, and sometimes another, it follows that the other cannot understand him; for, in order to understand, we must have distinct ideas. A scientific definition is nothing but an ordinary one, only definite and unchangeable in its meaning.

If an agriculturist speaks of his cattle which give him milk and manure, his neighbour agriculturist understands that he means his "cows." The production of milk and manure does not, however, constitute the scientific definition of a "cow," for it does not exclude the idea which might be entertained by a third person that all animals which produce milk and manure are cows, or that a cow which gives only manure and no milk is not a cow.

The same holds good in chemistry with the notion conveyed by the word *soil*, and also with regard to what is called *experience;* the word *experience* in an unscientific sense always recals to mind the man who was seized with sneezing when it thundered, and who always went out with his umbrella in the most beautiful weather, if he had happened to sneeze in the morning, because, *according to his experience*, it was sure to be a thunder storm.

In the argument of our teacher of agriculture, there is, in fact, "no soil"—that is, nothing which an agriculturist from *experience* knows as such; but it cannot be denied that the argument takes a wide range and view of things.

The diminution of volume of the soil by the removal of mineral substances is evident; amounting yearly, if my calculation does not mislead me, in the three-crop rotation to the $\frac{1}{40}$ part of the thickness of a spider's thread. Equally clear and intelligible is the way in which nature is made to help plants, when the surface soil is exhausted, to obtain their nourishment from the sub-soil. The soil is in this respect made to comport itself to plants somewhat like a mixture of $\frac{9}{10}$ of quartz and $\frac{1}{10}$ of peas to a brood of fowls. When these birds have picked the peas from the soil, then comes the cock, like nature, afterwards, and scratches and scrapes away the useless matters. The sagacity of our teacher will of course also explain what becomes of those four million kilogrammes of waste matter which are yearly washed away in this manner from 1829 hectares; as well as show that the loss of mineral matters is of no importance to those neighbouring fields from which the wind and rain have carried them to our own.

The experienced teacher of practical agriculture, in order to refute a deduction of exact science which he holds to be false, invents a case which does not exist in nature, and is simply impossible, or at least unknown; and the conclusion to which he had previously carefully prepared his premises to lead, he applies to actual cases. He imagines a fertile field extremely rich in the ash-constituents of plants, and supposes it to gain from below, in the most dexterous manner, what is taken from the surface; and having in this way made it inexhaustible, he then draws the conclusion that all fields which are fertile, must comport themselves exactly like this imaginary field. It follows, then, as a matter of course, that the worst soils, under which can be understood only those which are absolutely sterile, must have required a supply of ash-constituents from the very beginning; for it is impossible to assume that, in the absence of all mineral food, which is taken for granted to be the case, they could have produced crops without these ash-constituents. It is therefore evident that if all fertile soils are inexhaustible in mineral matters, it is only the unproductive which require a supply of these substances in order to become productive, and a renewal of the wasted portion in order to remain fertile.

If an ignorant peasant, who has for thirty years seen crops follow the ploughing and sowing of his land, who knows that his father and grandfather had also reaped for thirty years from the same land after ploughing and sowing, believes himself entitled from these facts to conclude that this same land will still yield crops for thirty, sixty, a hundred years, or for an indefinite period, we must hold him excused on account of his ignorance. But when this peasant acknowledges that his grandfather, father, and he himself, have been obliged to manure this land each year, and then asserts that his field has never received ash-constituents in the manure, or that the ash-constituents it received have produced no effect upon the crops, and that their supply has consequently been of no advantage, we turn from him with pity.

If the peasant had been capable of making a correct observation, he would probably have perceived that his manure heap constantly diminished in activity, and that his grandfather with very little manure obtained much larger corn crops than he now does with all his manure; he would further have observed that he has now been obliged to include in his rotation plants which were not required by his grandfather, in order to maintain the productiveness of his fields for corn crops.

We have believed that the object the agriculturist had in view was the production of grain and flesh, and that the thoughts of the guides and teachers of practical husbandry had been directed to ascertain the best means of maintaining the grain and pasture fields in a uniform condition of fertility. We are now taught better by the writings of our modern teachers of agriculture: the production of flesh and grain is subordinate to *that of farm-yard manure.*

For cereals, the soil, they tell us, is always fertile if there be only enough of manure. "Above all things let us have fodder enough; the cereals will then follow of themselves." "Science does not teach agriculturists much when she tries to teach them to force nature," "when she tries to make them do without farm-yard manure." (W. S., 127.) "From the necessity for the rotation of crops agriculture does not wish to be emancipated, for farmers could even now free themselves partly from it if they could only manure more largely." (W. S., 129.) "Most agriculturists would undoubtedly much rather never cultivate anything but wheat and rapes; but this would never do, for the soil must have its farm-yard manure, and without a proper rotation farm-yard manure cannot be made." (W. S., 129.) "Farm-yard manure may be termed the raw material, which agricultural industry is to convert into marketable articles." (W. S., 124.) "A rich soil is consequently one which produces much manure, and a poor soil one which produces little. Hence, therefore, the division of plants into *manure-economising, manure-exhausting,* and *manure-enriching* plants. Now, as clover and lucerne are the real manure-producing plants, and manure is the soul of agriculture, everything depends upon them."

Our practical teachers have reduced, as we see, the most difficult of all trades, which manufactures its products with the most complicated of all machines—organised beings—and the pursuit of which is dependent on influences over which human power has no control, to a most simple fundamental principle, intelligible to the most stupid peasant-boy, viz., the *production of manure by fodder plants.*

To what results then has this excellent teaching, this outcry after manure, led? Clearly and distinctly may the present condition of our fields be recognised by the following entreaty and appeal to our sympathy and compassion:

" *Were science only to give us the means to enable us to cultivate these plants (clover, lucerne, esparsette) upon the same ground with uniform success, more frequently than is the case with our present system, then indeed would the philosopher's stone be found for agriculture; for as to the conversion of these plants into the forms adapted to the wants of man, we would look to that.*" (W. S. 127.)

This, then, is the result of the doctrine of these wise, clear-sighted, and skilful men, who assert that fertile soils are inexhaustible in the mineral food of plants.

To procure farm-yard manure, science is good enough; they wish to learn nothing from it, but only to obtain a small piece of the philosopher's stone. Then these *experienced* individuals, who are crammed full of so much information in chemistry, geology, botany, &c.,

will procure us flesh and bread in abundance: this every simple peasant can do if we only give him manure. Hence, little "Japhet in search of his Father," the poor child called "Mineral Theory," was so ill-used and ridiculed, because he was of opinion that the big purse would at last be emptied, by always taking out money without putting any in. But who could have thought twenty years ago, when there was plenty of manure, that it would ever occur to these obstinate and wilful fodder plants to produce no more manure, and no longer to *spare* and *enrich* the ground? The soil is naturally not the cause of this; for they teach that it is inexhaustible, and those who have still manure enough believe that the source from which it is derived will always flow. Truly, if this soil could cry out like a cow or a horse which was tormented to give the maximum quantity of milk or work with the smallest expenditure of fodder, the earth would become to these agriculturists more intolerable than Dante's infernal regions. Hence, the advantageous prosecution of this system of modern agriculture is only possible on large estates, for the spoliation of a small one would soon come to an end. Instead of stealing the leather, if they had bred the calf, it would have grown to an ox, and then we should have been saved from the fear of going barefooted at last.

But we need not yet despair: These wise, prudent, and experienced men have found out the means of putting an end to the deficiency of manure. These means, they tell us, consist simply in making use of *fresh*, instead of *rotted*, farm-yard manure. If short-sighted, careless agriculturists, who do yet not follow this plan, would only put it in practice, many of the complaints about deficiency of manure would cease.

"*Notwithstanding the general outcry about want of manure*, and all the trouble taken to increase vegetation; notwithstanding the great cultivation of fodder plants to produce farm-yard manure, it is allowed, nevertheless, when made, *to go to waste on the dung-hill.* We may assume that in our system of farming, the manure is carted out on an average at most half-rotted. Before the manure arrives at this state, it loses 25 per cent. of its mass, consisting chiefly of *precious nitrogen; I will here, however, estimate the loss to be equal in value to what is left.* If all agriculturists would employ their manure as fresh as possible, so that at most no more than 5 per cent. be lost, the increase of our cultivated plants would amount to 20 per cent. Not only would this 20 per cent. of the whole food employed in increasing the crop be converted into vegetable matter, but by its means a further quantity would also be drawn from the air and the soil." (S. 131.)

"An increase of the production of fodder is, however, not required, so long as we do not wish to augment vegetation still more. Hence, the 20 per cent. of dung capital, could be solely expended on the greater production of grain, which would thus become so much larger, in comparison with that of cattle, which remains the same. The supply of grain would consequently be greater, its price more moderate, and this would put itself more in equilibrium with the production of cattle: producers and consumers would be equally benefited. But greater advantages would also be attained; for, instead of expending upon the growth of corn the 20 per cent. of manure saved, agriculturists could also *diminish* their cultivation of fodder by 20 per cent. The production of corn remaining the same, that of cattle would be decreased 20 per cent., and hence the latter would rise in price, whilst that of corn continues the same. Were the 20 per cent. of manure saved, chiefly devoted to the growth of corn, and to a smaller extent to that of fodder, producers and consumers would derive benefit from this plan; only on the part of the former it would be greater, and at how small a cost—*all by means of the 20 per cent. of volatile matter which careless agriculturists lose by the neglect of the manure on their dunghills.*" (S. 132.)

Had there been any doubt on the point, this proposition would incontestably prove that the modern teacher of practical agriculture puts not the slightest value on the mineral constituents of stable-dung, but ascribes its entire effect to the combustible matters it contains. With the 20 per cent. of these matters, which fresh farm-yard manure loses by rotting, the practical man would make us believe that 20 per cent. more corn, clover, or flesh could be produced.

Because, straw manure had accidentally improved the physical quality of his land, and consequently exerted a more favourable action than short rotted manure, he teaches, in opposition to thousands of well established facts, that fresh manure must produce larger crops on *all* fields. He would make us believe, that when we simply take away the grain from our fields and plough in the straw, their fertility in each succeeding year must receive an additional increase equivalent in amount to what the straw loses, when it has been used as litter, and converted into manure!

Now, what is the cause of this great effect of fresh farm-yard manure, and its advantage over that which is well rotted? This, also, the man of practice tells us: "*In fresh manure there is more nitrogen than in old; the latter, on the other hand, contains more ash constituents.*" (W. S. 101.) Hence, fresh manure is more efficacious than old! Chemical analysis, indeed, proves, that *rotted farm-yard manure contains more nitrogen than fresh*, but in such matters practice must decide; and since, according to its teaching, the larger crops *could only have been the result* of the greater supply of *nitrogen*, it follows that chemical analysis must be in error.

But, after all, the additional 20 per cent. of manure which the land of our experienced teacher of practical agriculture obtains, appears to him far from sufficient, for he says: "Now, since straw and fodder, the materials for manure, are expensive, and manure must be had at almost any price, and the latter comes tolerably dear in consequence of the low price of cattle produce, agriculturists have naturally been seeking for a long time back for a substitute for manure. Such a substitute has been lately found in Guano."

Now, what is guano, and in what way is its employment advantageous to the agriculturist?

Guano consists of the residue of the excrement of fish, that is, flesh eating birds, and contains essentially the ash constituents of the flesh of fish, together with a certain quantity of ammonia salts.

Comparison shows that the better sorts of guano contain the ash constituents of grain, together with a certain quantity of phosphate of lime, which forms an essential element of the ash of our meadow and pasture plants. The effect of guano on our corn fields is therefore palpable. We have for hundreds of years removed from them, by the cultivation of corn, the ash constituents of grain, and by rearing cattle, we have also taken away a large quantity of phosphate of lime (in their bones) *without replacing any of these matters*; we have, however, left them the conditions for producing straw.

The increase of the produce of grain, by manuring with guano, is the natural consequence of the restoration of the elements of grain, which we have been at so much pains to drag from our fields. The astonishment of the corn producer at the powerful effect of guano, after all, arises from the fact that he sees a few handfuls of this substance acting more efficaciously than a cart-load of stable-dung; and because in looking at the *smallness* of the quantity of the guano, and comparing it with the *large* increase of grain, his ideas about manure are completely confounded.

To our experienced teacher of practical agriculture, guano is, as a matter of course, only a means *for producing manure.* Guano in an agricultural sense, is a "supplemental manure," which we ought to use so long as the supply lasts, for the purpose of *increasing our dung capital.* (W. S. 137.)

That the effect of guano depends on the volatile and combustible materials it contains, cannot of course admit of a question; let us hear what would be the result of its employment.

"The general use of guano can only be attended with a result similar to that which would take place if the 20 per cent. of manure hitherto lost from the dunghills were in future to be made use of." "Those agriculturists who still allow their manure to rot, hence clearly act foolishly in buying guano before they derive the fullest advantage from their own manure." (W. S. 136.) No value whatever is put on the ash constituents of the guano.

The ideas of our teacher of practical agriculture of the comportment of a soil under cultivation are not less peculiar.

"*Notwithstanding that plants are yearly reaped, an* *equal quantity can, on an average, be continuously removed every year from the soil* (for example, from an unmanured meadow). *This is the natural production of the soil. The soil remains, and continues to remain at a fixed agricultural point of production.*" (S. 103.)

"If during a period of one or more years the plants which grow upon a soil die, and decay, an accumulation of decaying and decomposing products will thus be gradually formed in it. There is thus furnished *a further source of both kinds of food*, and the development of plants is consequently promoted." (S. 104.)

"By further new and increased crops more *ash constituents than formerly*, as well as products of decay, will be *removed* from the soil."

"After a series of years, and a corresponding number of crops, the ground sinks again to its original degree of fertility—its fixed point of production. *It has again attained its original composition, and as nothing else has been changed*, this alteration of the soil must be *the probable cause of its increased and again diminished fertility.*"

"Stable-manure consists of decaying vegetable and animal matter, which also contains a certain quantity of ash constituents, hence the development of plants can be as well promoted by stable-manure as *by plants which decay upon the fields themselves.*"

From these propositions which are given as agricultural principles, it would follow that our cultivated fields comport themselves like unmanured meadows. Whether we cultivate grain, turnips, or clover, on one and the same field, we may fairly expect continuously, and without any application of manure, an average yearly crop of the same amount. This would be the natural production, or the agricultural fixed point of the soil!

If we leave meadow plants, corn, and clover, to die and decay on the field, manure accumulates in the soil and renders it more fertile. We obtain larger crops, and *withdraw by these means more ash constituents than before, in consequence of which the ground becomes poorer.*

Having followed this course for some years, the ground, robbed of its ash constituents, sinks back to its fixed point of production. It has again attained its original composition (that is, *it contains no more combustible matters than at first*), *and since nothing further has been changed* (*as everything depends upon this*), then this alteration of the soil—*the diminution and increase of combustible matters in it*—must be the probable cause of its increased and again diminished fertility.

The views cited above are not those of a single man, but with few exceptions belong to the whole class of practical agriculturists. What the author teaches is not an invention of his own, but he retails what he has learned. I have reviewed these doctrines, not for the purpose of exercising indiscriminate criticism, but because, without holding up to view the opinions of practical men, my own peculiar doctrines might appear to many in the present day incomprehensible, and perhaps, at no distant date, vain and objectless.

I need not add one word more; the passages just cited give the key to the conflict which has been raised about the recognition and application of scientific principles in practice; that the latter do not enter into the circle of ideas of practical agriculturists will now be easily understood.

Many agriculturists are of opinion that in this contest it is a question of words, not of principles, and that an understanding is possible. They think that if they allowed the action of mineral substances, then, in justice, the other party will acknowledge that of combustible substances, and thus the conflict would come to a happy termination. If the contest for the recognition of scientific principles had in fact no higher object than the admission into broth of onions previously forbidden, or the compromise that eggs may be opened at both ends, then they are right.

They are right so long as they entertain the opinion that the best master brewer of the best Bavarian beer is the fittest man for a chair of brewing.* I, for my

* This sentence refers to the arrangement of many German agricultural institutions. They are in general endowed with a considerable extent of land, which is managed like other government lands. The produce of the soil finds its way into the public coffers. The school and the land are united with each other in the person of the Director, to whom is intrusted the cultivation of the ground and the superintendence of the instruction; in the net proceeds of the farm he has commonly a share. There are men who are endowed with capabilities for both offices, but it usually

part, do not believe that such a man should be recommended as the proper person for imparting the scientific principles of brewing, even though he had for twenty years conducted the most extensive business of this kind with skill and profit.

happens that a good practical man is not the best instructor, and the latter is not generally an individual who sets much value on obtaining great profits from the land.

LETTER X.

The empirical agriculturist is a trader—The duties of the empirical and rational agriculturist—Views of Albrecht Block—Rotation of crops not unimportant; an underground crop is followed by a better cereal—Cropping of land without manure, and the removal of produce, cause exhaustion—The spoliation system of agriculture—Exhaustion of the lands in North America by this system—Exhaustion of the Minas Geraes fields—High farming is a more subtle system of spoliation of the soil—Mutual relation of clover, turnip, and corn crops; and the results of removing from the lands the mineral constituents of these crops respectively—The German system of farming before the Thirty Years' War—The German three-field system of rotation—Introduction of clover cultivation into Germany—Opposition to its introduction—False teaching in connection with the value of manures.

The empirical agriculturist is a trader who produces meat and corn; without troubling his mind about collateral matters, he simply seeks to gain from his fields the largest possible crops, and he holds that system of cultivation as the best which will yield him the richest harvest, in the cheapest way, and in the shortest time. And why should he not? The same system of husbandry which he pursues has been followed for centuries before his time, and he simply practises the lessons taught him by those who preceded him in the farming of his land. As *they* never inquired what might ultimately become of the land, and what effect their system of cultivation might have upon it—why should *he* trouble his mind about it? If he can succeed in making a living out of his farm, clearing his rent, or the interest on his capital, and acquiring some property besides, this alone is proof positive to him of the soundness of his system. When he happens to remark a falling off in his wheat, clover, turnip, or potato-crops, he tries whether growing some other varieties on his fields will answer better, and attributes the diminished fertility of the soil to any and every event that may have occurred since he first remarked the decrease. Thus he will complain that his fields no longer yield the rich crops of former years, ever since the adjoining wood has been cleared; or ever since the railway was made; or the chemical manufactory established in the neighbourhood; or he will attribute the falling off to the injurious influence of the numerous thunderstorms in the preceding year; or to any other imaginable and imaginary cause—except always to *himself and his system; the idea that the fault might possibly lie with him or his system can find no place in his mind;* for, has he not pursued the same system for years with the very best results; his dungheap is as large as ever, and the land does not look changed in the least?

As a trader he is in the position of a shoemaker who must not devote his attention to investigations into the origin of sole and other varieties of leather, the process of tanning, and the properties which constitute the good quality of the article, and who, were he to do so, would most likely supply the public with boots and shoes, neither cheap nor overwell made. The true shoemaker who thoroughly understands his craft, does not trouble his mind about such matters; he leaves to others, whose special business it is, the task of studying them; if he happens to be a man of some education, he studies the anatomy of the foot, and makes shoes that shall delight the female eye, and boots that shall not distort the shape of the foot, nor produce corns. Such a pearl of a shoemaker would never dream of disputing with the man of science about leather, pitch, and thread, as he would have no time for such discussions; he would on the contrary be grateful to the chemist for teaching him how and by what marks or signs to know and select the sorts of leather for soles and uppers best suited for the purposes for which they are severally intended.

The scientific farmer and teacher of husbandry has a higher task assigned him. It is for him to rise above the mere routine teachings of empiric observations; to guide and keep the practice of farming in the right path; to subject to a rigorous and searching investigation the methods of husbandry adopted and pursued by the empirical farmer, in order to point out to him the why and wherefore, and to lead him to a proper sense and rational appreciation of his doings, and their results and consequences. The rational agriculturist has to inquire whether his system accords with established truths and natural laws, or is in opposition to them; and above all, he must never lose sight of the one great principle, that the aim of true practical husbandry must be directed, not merely to the present production of the largest crops, but to the securing of a constant return of such crops.

If the teacher of husbandry, instead of assisting and supplementing in this way the practice of agriculture, indulges in views that are simply calculated to vindicate the farmer in his empirical proceedings;—if, whilst clearly seeing that this empirical system of husbandry is opposed to established natural laws, he draws therefrom the conclusion that these natural laws may possibly not apply to practical farming, and that agriculture accordingly may not be subject to natural laws;—if he asserts that the practice of husbandry, and the science of agriculture may be treated as separate and distinct questions, and that a thing may possibly be *true in science that is false in practice*,—if such are the doctrines propounded by him, he stands as an agriculturist far below the practical farmer, who fails to derive instruction from these lessons, simply because he finds in them nothing but a reflex of his own doings in the cultivation of his land, garnished with misconceptions and false views.

A simple comprehensive natural law governs the greater or less abundance, and the longer or shorter succession and continuance of the crops that can be grown on a field. The greater or less abundance of the yield of a field depends upon the aggregate sum of the conditions of fertility therein existing; the longer or shorter *continuance and succession* of the crops that may be grown thereon, depend upon the *unaltered condition* of this aggregate sum.

A practical agriculturist, Albrecht Block, is reported to have said: "*A farmer can afford to sell and permanently alienate only that portion of the produce of his farm which has been supplied by the atmosphere—a field from which nothing is abstracted can only increase, not decrease in productive power.*" If we express the same idea in another form, viz., "*A farmer may sell and permanently alienate all that portion of the produce of his farm which has been supplied by the atmosphere—a field from which something is permanently taken away, cannot possibly increase or even continue equal in productive power,*" the axiom thus enunciated is simply a natural law. In this opinion of this truly experienced man, to whom future agriculture will surely raise a monument, is at once expressed the whole foundation and groundwork of rational farming, and all the knowledge that the science of nature can teach the practical farmer.

Every act of the farmer which violates the laws of nature, must justly be branded as *an act of spoliation.*

If a farmer grows in three several fields alternately potatoes, corn, and vetches or clover, or on one and the same field successively potatoes, corn, and vetches, and *sells* the produce obtained—the corn, the potatoes, and the vetches,—and *continues to act in this manner for many years, without manuring his land,* the humblest peasant will predict the inevitable end of such a system; he will tell him that a continuance of this kind of farming is impossible for any length of time. Whatever grass, corn, tuber, or other crop may be selected, and in whatsoever rotation,—the field will ultimately be brought to a state of exhaustion by it; the corn will only yield an amount equal to the original seed, the potatoes will no longer produce tubers, and the vetches or the clover will die away after barely appearing above ground.

These facts undeniably demonstrate that there exists no plant that could possibly be said to *husband the resources* of the soil, and *à fortiori*, none that can possibly be had to *enrich* it.

Innumerable facts have taught the practical farmer, that, in many cases, the successful cultivation of an after-crop on a field depends upon the nature of the preceding crop, and that it is by no means a matter of indifference in what succession or rotation he grows his crops. The previous cultivation of some underground crop, or some plant with extensive root ramifications, will tend to make the soil more favourable for the subsequent growth of a cereal. The latter will in such cases thrive better, and it will do so without the use (with the sparing application) of manure, and will yield a more abundant crop. But as regards *succeeding* harvests, there has been in reality no *saving* of manure, nor has the field *increased* in the conditions of its fertility. There has been no augmentation in the gross amount of the elements of food in the soil, but simply an increase of the available effective portion of these elements, and an acceleration of the results in a given time.

The physical and chemical *condition* of the fields has been improved, but the chemical *store* has been reduced; *all plants, without exception, exhaust the soil, each of them in its own way, of the conditions for their reproduction.*

There are fields that will yield without manuring for six, twelve, fifty, or a hundred years successively, crops of cereals, potatoes, vetches, clover, or any other plants, and the whole produce can be carried away from the land; but the inevitable result is at last the same, the soil loses its fertility.

In the produce of his field, the farmer sells in reality his land; he sells in his crops certain elements of the atmosphere that are constantly being replaced from that inexhaustible store, and certain constituents of the soil that are his property, and which have served to form, out of the atmospheric elements, the body of the plant, of which they themselves also constitute component parts. In altogether alienating the crops of his fields, he deprives the land of the conditions for their reproduction. A system of farming, based upon such principles, justly deserves to be branded as a system of spoliation. Had all the constituents of the soil, carried off from the field in the produce sold, been, year after year, or rotation after rotation, completely restored to the land, the latter would have preserved its fertility, to the fullest extent; the gain of the farmer would, indeed, have been reduced by the re-purchase of the alienated constituents of the soil, but it would thereby have been rendered permanent.

The constituents of the soil are the farmer's capital; the elements of food supplied by the atmosphere, the interest of this capital: by means of the former, he produces the latter. In selling the produce of his farm, he alienates a portion of his capital and the interest; in returning to the land the constituents of the soil removed in the crops, he simply restores his capital to his field.

Every system of farming based on the spoliation of the land leads to poverty. The country in Europe which, in its time, most abounded in gold and silver, was, nevertheless, the poorest. All the treasures of Mexico and Peru brought to Spain by the richly laden silver fleets, melted away in the hands of the nation, because the Spaniards had forgotten, or no longer practised, the art of making the money return to them, which they had put into circulation in commerce to supply their wants; because they did not know how to produce articles of exchange required by other nations, who were in possession of their money. There is no other way of maintaining the wealth of a nation.

It is not the land in itself that constitutes the farmer's wealth, but it is in the constituents of the soil, which serve for the nutrition of plants, that this wealth truly consists. By means of these constituents alone, he is enabled to produce the conditions indispensable to man for the preservation of the temperature of his body, and of his ability to work. *Rational agriculture*, in contradistinction to the spoliation system of farming, is based upon the principle of *restitution;* by giving back to his fields the conditions of their fertility, the farmer insures the permanence of the latter.

The deplorable effects of the spoliation system of farming is nowhere more strikingly evident than in America, where the early colonists in Canada, in the State of New York, in Pennsylvania, Virginia, Maryland, &c., found tracts of land, which for many years, by simply ploughing and sowing, yielded a succession of abundant wheat and tobacco harvests; no falling off in the weight or quality of the crops, reminded the farmer of the necessity of restoring to the land the constituents of the soil carried away in the produce.*

* *New York.*—In the debate on the Bill passed by the Lower House of Congress, by which a grant of six million acres of Union land is made to the several States, for the establishment and maintenance of agricultural and industrial schools, the mover of the Bill, Mr. Morrill, of Vermont, showed, in a most excellent speech, by means of exact statistical returns, how urgently these schools are required for the better education of our farmers, who at present, it would appear, are guilty of the grossest Vandalism in the management of their land. The speaker showed that we in America are far behind Europe in agriculture in general, and more especially in the modern scientific system of farming; and that the sad results of this state of things are even now becoming manifest to an

We all know what has become of these fields. In less than two generations, though originally so teeming

alarming extent. The honourable gentleman said, the general method of husbandry pursued in all parts of the Union was so bad and imperfect, that it must necessarily year after year more and more impoverish the soil; and the incessant drain on the natural productive power of the soil amounted simply to downright robbery, committed by individuals at the expense of the national property.

The following table in some measure shows the falling off that has taken place within a period of ten years in the annual yield of agricultural produce in several of the Northern States. The number of bushels of wheat produced was in

	1840	1850
Connecticut	87,000	41,000
Massachusetts	157,923	31,211
Rhode Island	3,098	49
New Hampshire	422,124	185,658
Maine	848,166	269,259
Vermont	495,800	535,955
Sum total	2,014,111	1,063,132
	Potatoes.	
Connecticut	3,414,238	2,689,805
Massachusetts	5,385,652	3,385,384
Rhode Island	911,973	651,029
New Hampshire	6,206,606	4,304,919
Maine	10,392,280	3,436,040
Vermont	8,896,751	4,951,014
Sum total	35,207,500	19,418,191

In many Southern States this falling off in the produce of the soil is equally significant. The number of bushels of wheat produced was in

	1840	1850
Tennessee	4,569,692	1,616,386
Kentucky	4,803,162	2,142,822
Georgia	1,801,830	1,088,534
Alabama	838, 052	294,044
Sum total	12,012,736	6,141,786

These figures show pretty conclusively that in all parts of the Union the land must have been deprived of some of its most essential elements, and with fertility, they were turned into deserts, and in many districts brought to a state of such absolute exhaustion, that even now, after having lain fallow

that its fertility is constantly on the decrease. In the State of New York there are now 300,000 sheep fewer than thirty years ago. Within a period of five years the decrease in the number of sheep in the State of New York amounted actually to nearly 50 per cent., and in the number of horses, cows, and swine to above 15 per cent. In 1845 the wheat crop in the State of New York amounted to 13,391,770 bushels; it has since then fallen off year after year, and last year it actually did not exceed 6,000,000 bushels.

The average produce of Indian corn was in 1844, 24·75 per acre, in 1854 it was only 21·02. The average yield of wheat was in Virginia and North Carolina, in the year 1850, no more than seven bushels per acre, and in Alabama five bushels. While the cotton crops in the new territories of Texas and Arkansas yield annually an average produce of 700 to 750 lbs. per acre, the old fields of South Carolina produce only half as much. The tobacco crop of Virginia was 18 million lbs. less in 1850 than in 1840. No kind of crop has proved so injurious to the fertility of the soil as that of tobacco, and in many of the States whole tracts of land are now lying waste, that for a century had been made to yield, year after year, crops of tobacco, maize, and wheat. There can be no doubt but that three-fourths of the arable soil of the Union are undergoing, to a greater or less degree, this exhaustive process. Dr. Lee, of Georgia, estimates the decrease in the annual produce of the soil of 100 million acres of land in the United States, at ten cents per acre. This would give a total of 10,000,000 dollars, making the amount lost equal to a capital of 166,666,666 dollars—a larger sum than all our federal and states taxes together.

In other branches of husbandry also enormous losses are caused by the want of proper information on many essential points—a want which can only be remedied by the establishment of agricultural schools. One of the ablest agriculturists in Massachusetts estimates the annual loss to the States, in cattle of all kinds, and in the produce of the dairy, &c., at several millions. There are about 447,014 horses in the State of New York, on which, from the prevailing ignorance of the veterinary art, there is an annual loss of not less than two million dollars.

These statistics could not, of course, fail to produce the impression intended, and the House gladly entertained the motion to establish agricultural and industrial schools. It would be a pity if the Senate should not be able to find time before the approaching adjournment to discuss and adopt the measure.—Allgemeine Zeitung, No. 175. Supplement of June 24, 1858.

more than a hundred years, they will not yield a remunerative crop of a cereal plant.

As every agriculturist in Europe has a notion that his system is an exception and better than that of others, and that, *judging from his own experience*, his fertile fields require no restoration of mineral matters to keep them up to the proper degree of productive power, so every early colonist also believes at first that his land, for the crop which he grows on it, forms an exception to other fields. He also trusts to his experience to insure an infinite succession of rich harvests; but even ere his children are grown up, he finds out his mistake. His farm passes into the hands of another colonist, who continues to despoil the soil in the same way as his predecessor, only with a larger expenditure of capital and labour. When he, in his turn, perceives that the plough will no longer suffice to keep the yield up to the former height, the land is then finally handed over to the tender mercies of the German colonist, who has been taught to look upon dung as the soul of agriculture,—a maxim of specious wisdom, of which his predecessor knew nothing, and the new owner then sets about despoiling the soil after his own fashion.*

* "Agriculture, in so far as I had occasion to inquire into the matter, is in a most primitive and unsatisfactory state in the province of Minas Geraes. It consists simply of a system of downright spoliation, disproportionately large quantities of the mineral constituents being constantly taken off, without the restoration of any portion whatever. Thus, for instance, they make a so-called *Roca*, *i. e.*, the trees and underwood are cut down on a certain

The European system of cultivation, called *high farming*, is not that open system of robbery of the American farmer, followed by the utter exhaustion of the soil; but it is a more refined species of spoliation, which at a first glance does not look like robbery. It is spoliation accompanied by self-deception, veiled under a system of teaching, the very basis of which is erroneous.

The simplest peasant has sense enough to see, and

tract, and towards the end of the dry season burnt on the spot; three or four harvests are then taken from the land so prepared, and it very often occurs that among these there are two Indian-corn crops in immediate succession. After this the field is allowed to lie fallow until it is again sufficiently covered with brushwood, when the same process is repeated; the interval varying between three and twelve years, according to local conditions and to the wants of the proprietor. It is quite evident, that the soil here has never had restored to it the smallest portion of the mineral constituents removed by the crops. No wonder, then, that there should be universal complaints in the province of the constantly increasing sterility of the *Rocas*. One of the more intelligent planters of the province told me that, of all the plants grown there none showed so large a falling off as the sugar cane, and that he at present reaped, on the same *Rocas*, only a third of the produce obtained by his father 55 to 60 years ago; and yet, he remarked, somewhat naïvely, he was much better off with his small crop, than his father had been with the larger one, for the latter (his father) had barely been able to realise a milreis for the cask of Cachaza (brandy), whereas he himself had last year received 14 milreis for the same. Now this man was perhaps right in his way; but how will it fare hereafter with his son, if he continues the same system, and the price of Cachaza happen to fall again? In the province of Bahia, the falling off in the sugar-cane crops is so great, that about a twelvemonth since a number of planters contrived to send out a ship to bring from several distant ports new sorts of sugar-cane. They attributed the falling off in the produce of their plantations simply and solely to the degeneration of the cane, without reflecting that by the incessant cultivation of the plant on a large scale, their land had been most enormously drained of the conditions of its fertility."—*J. J. von Tschudi's Journey through the Province of Minas Geraes.*—Allgemeine Zeitung, No. 47, May 27, 1858. Supplement.

all agriculturists agree with him, that clover, turnips, hay, &c., cannot be sold off from a farm, without most materially damaging the cultivation of corn. Every one willingly admits that the sale and exportation of clover, turnips, &c., exercise a detrimental influence on the growing of corn. "Above all, let us take care to have plenty of fodder, the corn crop will then take care of itself." But that the *exportation of corn* may possibly exercise an injurious influence on the cultivation of clover or turnips, that it is above all indispensable to restore to the soil the mineral constituents of the *corn*, to enable the clover or turnip crop in its turn to "take care of itself,"—in other words, that in order to grow clover, turnips, &c., we must manure the land—this is a notion utterly incomprehensible, nay absolutely impossible, for most agriculturists. For, is not the clover grown for the sake of the manure? What advantage, then, would there be if it were necessary to manure again to produce the clover? This clover the farmer expects to grow for nothing. From this total misapprehension of the very foundation of all true industry, spring all the errors and defects of the prevailing system of cultivation.

The mutual relations existing in the order of nature between the two classes of plants, are, however, as clear as daylight. The mineral constituents of the clover, turnips, &c., and of the corn, form the conditions for the production of the clover, turnips, &c., and of the corn, and they are in their elements quite identical. The clover, turnips, &c., require for their growth a certain amount of phosphoric acid, potash, lime, magnesia—so does the corn. The mineral constituents contained in the clover are the same as those in the corn, *plus* a certain excess of potash, lime, and sulphuric acid. The clover draws these constituents from the soil; the cereal plant receives them—we may so represent it—from the clover. In selling his clover, therefore, the farmer removes from his land the conditions for the production of corn; no mineral constituents are left for the corn. If, on the other hand, he sells his corn, there will be no clover crop in the following year; for in his corn he has sold some of the most essential conditions for the production of a clover crop.

The peasant expresses in his own way the part which the cultivation of clover and other fodder plants performs in the economy of his land, when he tells us that he regards, as a self-evident proposition, that a farmer must not sell his stable manure; that without manure a continued cultivation of his farm is impossible; and that a farmer who sells his clover and other fodder plants, does actually sell his manure, and that there is no need of the wisdom of the chemist to make him understand this. This is very true; for so far as that goes, the common sense of the simplest peasant will guide him. But that a farmer, in selling his corn, is still actually parting with his manure, would, however, appear to be beyond the comprehension of the great majority of the most enlightened agriculturists. The dung contains all the mineral constituents of the clover and other fodder plants, and these consist simply of the mineral constituents of the corn, *plus* a certain quantity of potash, lime, and sulphuric acid. Now, as the whole dung-heap consists of parts, it is quite evident that the farmer must not sell any part thereof; and that, if it were possible to devise a means of separating the mineral constituents of the corn from the others, those very mineral constituents so separated would have the very highest value for the farmer, as they form the most essential condition for the production of corn. Now, in the *cultivation of corn* this separation is actually effected, for these mineral constituents of the manure are converted into constituents of corn. In selling the corn produce of his fields the farmer parts, therefore, with a portion, and, indeed, with the most efficient portion of his manure.

Two dung-heaps of equal appearance, and seemingly equal quality, may have a very dissimilar value for the cultivation of corn; if one of the heaps contain twice as much mineral constituents of corn as the other, it has double its value. By the exportation of the mineral constituents of corn, which the latter had drawn from the manure, the dung of the farm is made to suffer a progressive diminution of its efficiency for future corn crops.

In whatever light, therefore, we may look upon the exportation of corn, or any other produce of the fields, to the farmer who omits to restore to the soil the mineral constituents removed from it, the ultimate result will always be exhaustion of his land. The continued exportation of corn renders the soil unproductive for clover, or deprives the dung of its efficacy. Dung, in itself, has an agricultural value only in so far as it contains the conditions necessary for the growth of the saleable produce; the mere size or extent of a dung-heap does not constitute its value.

The reader will now understand what a total want of all knowledge there is in the precept, that dung is the raw material to be worked and made into produce by agricultural industry; and how essentially that axiom and opinion have contributed to blind the eyes of agriculturists to the clear perception of the sole and original source of all agricultural production, and of their own prosperity—*viz.*, *the soil.*

If our farmers had to till the teeming virgin soil of America, Australia, or New Zealand, a professor of agriculture, who would try to persuade them that "manure is the soul of agriculture," would simply appear ridiculous in their eyes, as their own experience would show them that the fields yield rich harvests without manure.

In our exhausted fields the roots of the cereal plants find no longer, in the upper layers of the soil, a sufficiency of food for a full crop; the farmer, therefore, grows on these fields clover, turnips, and other plants, which, with their wide-spreading and deep roots, penetrate through the soil in all directions, and by the great surface of their roots render available, and assimilate to themselves, those constituents of the soil which the culmiferous plant requires for the formation of seed.

In the remains of the roots, stalks, leaves, and tubers of these plants, which the farmer puts in the form of manure on the upper layers of his soil, he returns to it in a concentrated form the deficient corn constituents required for one or several full crops. These indispensable elements of food, which were before scattered throughout the subsoil, have by the green crops been collected from it and added to the surface soil. In effecting this object, the clover and fodder plants can no more be regarded in the light of creating the conditions necessary for the larger corn crops, than the rag-gatherer, who collects the materials for manufacturing paper, can be looked upon as the producer of those rags.

The American farmer despoils his field *without the least attempt at method in the process.* When it ceases to yield him sufficiently abundant crops, he simply quits it, and, with his seeds and plants, betakes himself to a fresh field; for there is plenty of good land to be had in America; and it would not be worth his while to work the same field to absolute exhaustion. But our modern system of "high farming" is an *organised* system of spoliation—the last, highest, and most finished degree of the art of wearing out the soil.

Before the thirty years' war the population of

Germany was not smaller than at present. Every individual naturally required at that time for breathing and working, the same supply of oxygen and of the elements of muscular force as people require at present for the same purpose. The agriculturist of that day pursuing the same *spoliation system as the American farmer* of our day, produced the same supply of carbonaceous and nitrogenous food as is grown at present; only he *took more time to do so.* There were years of scarcity, the effects of which were more severely felt then than they are now, because they were not mitigated at that time by a supply of the deficiency from America, Hungary, or the great granary of South Russia; but in ordinary years the land produced plenty. One year, Winter corn was grown; the next year, Summer corn and turnips (*Stoppelrüben*); the third, the field was allowed to rest; there was no other rotation except with pulse. What is now-a-days called stall-feeding, was entirely unknown. The meadow supplied winter fodder for horses; cattle and sheep found their food on the commons or fallows, and in the woods. The agricultural system of that period might be likened to the system of the man who had an income of one florin a day, and who let the florins of one week accumulate in order to spend them in the next week. On Sunday he found himself accordingly with seven florins in his pocket, and could therefore now afford to spend on the Monday following four florins; on Tuesday, three florins; and on Wednesday, other three florins, and in this manner was able to buy a number of things which he would have been unable to procure with a daily expenditure of one florin.

The system of letting the land lie fallow every third year did not make the soil more fertile, or add to the elements and conditions of its productiveness; but it served to render those elements and conditions more available within a certain time. Except by conveying to it a supply of fertilising material, it is quite impossible to make a field richer and permanently more productive. That the field *did* yield a more abundant crop after having lain fallow was owing simply to the fact that the soil still contained a sufficient store of effective mineral constituents, only not in a state available or assimilable for the roots. The rest enjoyed by the field during fallow afforded time for part of their store to be made available as food, and in this way a remunerative crop was obtained. The overplus of the more abundant harvest which follows a period of fallow, is not a real addition to the revenue yielded by the field, but simply a saving from the preceding year, when the land was at rest. By means of this system the soil is somewhat more profitably despoiled of its resources, as the work of spoliation proceeds more leisurely. Time, people argued, costs no money, and fallow saves manure, an advantage which was clear to all. This system prevailed till towards the middle of last century. The peasantry, as a body, fell into a state of poverty and wretchedness, and the production of the fields continued decreasing.

In the seventeenth and the beginning of the eighteenth century, the culture of the vine was still flourishing in countless places in Germany ; fields upon fields were then occupied by vineyards where the grape now no longer grows ; the large tithe-cellars alone, which still continue to exist in many places, give evidence of the immense extent of the vine culture in by-gone days. With the vineyards the spoliation system of cultivation sooner produced its results ; for vineyards produce no manure, and as the corn growers found that the cultivation of their own fields stood in the utmost need of all their manure, the culture of the vine necessarily died out, like the flame of a lamp for want of a supply of oil.

" The only winter-food the farmer had for his cattle, besides bad and sour meadow-herbage, consisted of white turnips, carrots, cabbage, and potatoes ; and even of these there was no great store, because the fields had ceased to produce when unmanured. This scanty food was, throughout the whole winter, whilst it lasted, made still scantier by steeping and boiling to eke it out, and when at last it came to an end, the cattle had to starve on barley, oat, and pease straw. The milk, butter, and cheese yielded in return were little in quantity and wretched in quality. The coming of spring was anxiously awaited to get a few cuttings of the young wheat shoots, and the cattle were sent to the common to feed on grass, barely a couple of inches high, whence the poor beasts returned at night just as famished as when they had left the stable in the morning, looking like the lean kine that Pharaoh saw in his dream." This is the description given of the then state of agriculture in Germany by John Christian Schubert, whom the Emperor, Joseph II., created a Knight of the Holy Roman Empire, bestowing upon him the style and title of Ritter von Kleefeld (Knight of Cloverfield), as a mark of imperial appreciation of the eminent services rendered by him in the introduction of the cultivation of clover into Germany.

The new culture introduced by the worthy Knight was hailed with acclamation all over the Empire. The peasants who grew clover received silver "clover-dollars," to wear round the neck. *Stercutius*,* the God of Manuring of Ancient Rome, whose worship had been abandoned for 2000 years, was replaced on his throne; in Agricultural Educational Institutions altars were raised to him, at which his priests even to this day continue to sacrifice. But the God of the Dunghill proved capricious. He seemed to make some fields the special objects of his bounty, only to forsake them again after a time; and now, after a hundred years' sway, he has grown altogether stern and unkind. He no longer bestows his former rich gifts even upon his most assiduous worshipper, and from the very fields

* Stercutius, or Sterquilinus, according to some, one of the names of Saturnus. (See Virgil's "Georgics," by Voss, page 74.)

which he once seemed most to favour, he now withholds the power of producing the poorest crop of manuring plants. Therefore do his priests urgently supplicate for a small piece of the philosopher's stone to be offered as an oblation to the God of Manure, that he may relent, and make clover for manuring grow for the future on fields on which that plant will now no longer thrive. When at a later period the potato and the application of marl and gypsum to the land came to aid the beneficial efforts of the cultivation of clover, people trusted there would now be an end for ever to all want. The old spoliation system, first in its naked form, and then altered by the introduction of fallow, now underwent a further modification, based on the system of a well-known highwayman on the borders of the Rhine. He stripped the rich of their dollars, bestowed at times a penny on the poor, and for sport cut the buttons off their breeches.

According to his creed the wealth of the rich had been stolen from the poor, and it was but justice therefore to make them disgorge it.

Our high farmer acts upon a similar principle. In his corn crops he makes the (rich) clover disgorge as it were the dollars which it has extracted penny by penny from the (poor) field; and he fancies this system of robbery will last for ever, as his instructors have taught him that his land possesses the property of sweating penny pieces.

The consequence of this spoliation system upon the principle of the noble robber, are clear, patent, and obvious to everybody; never has the want of manure been more severely felt than at present. All the ways and means which so marvellously tended towards the end of last century to increase the productiveness of the land, are at present resorted to in vain; they fail to produce their former effect. The application of gypsum to the soil now makes the clover only more watery, without increasing the crop; land treated with marl is more unproductive than before. Were it not for the manure which the trees of the forest yield in many countries, the culture of the cereals would, in many former fertile districts, long since have come to an end, like that of the vine. The agriculturist in these parts now despoils the woods, as he formerly despoiled his fields, and he will continue this new system of depredation as long as it will answer! "If you will grow clover, and will strictly follow my directions," said the good Schubert to the peasants of his time, "you will have ample cause for rejoicing and for praising the Lord out of the fulness of your heart for his rich blessings. But bear in mind one rule, which I charge you now once for all to follow: never grow clover at the expense of corn, but grow it only in fallow, that it may cost you nothing—in other words, give up the practice of letting a field lie fallow." At that time there was no other system of husbandry known but the so-called "Three-fields-system," or system of triennial rotation. In twelve years cereals were grown eight times in a field, and clover four times. Where are those glorious days when the same field yielded in three years two crops of corn and one of clover into the bargain! Now-a-days high farming produces in 12 years only six corn crops. In Mecklenburgh good land gives only four corn crops in nine years. The original area on which fodder plants were cultivated, and which at the time proved amply sufficient to collect and concentrate the food required for the cereals, is therefore no longer large enough to keep up the supply, and it has become necessary to extend it. The cultivation of food for cattle takes up at present as great, and even a greater breadth of land than the raising of food for man; and men's minds and ideas have become so perverted, that this lamentable fact is actually looked upon in the light of a great improvement!

So long as those most interested in the matter, instead of reflecting upon the conditions on which the successful cultivation of all plants depends, and trying to discover these conditions and to understand their application in practice, seek to put agriculture into a healthy condition by "manure," a thing so very indefinite, indefinable, and variable in its nature, no real progress can be expected. For my part, I am quite aware, that science will for a long time to come, have to preach to deaf ears. So long as agriculturists derive from the spoliation of their own lands plentiful crops and a good income, there is no hope of the advent of a more rational system of husbandry. The field is to such men, simply a cow that gives them milk, but which they would feed with its own flesh, taken from its ribs; and the folly of such a proceeding will strike them only when the light shines through the hollow skeleton of their victim. Man is naturally prone to spoliation, and dreads nothing so much as to have to exert his mental faculties in the acquisition of what he needs; he is in many respects like a child in whose eyes the school and learning are the greatest of all troubles. Necessity is the only compulsory agent that will ever make him move, and this will come soon enough.

The dangers threatening the state and society from the wanton spoliation of our woods, led to the devising of our (German) present most admirable regulations for the management of our woods and forests. If our forests were parcelled out into as many portions and divided among as many foolish hands as our arable land, we should long ago have been without wood. There is the most imminent danger just now, that the rapidly progressing destruction of the Quinine or Peruvian bark-tree will, at no distant period, deprive society of one of the most invaluable medicinal agents; and our only consolation is, that when the last tree of the kind shall have fallen, the rational culture of the plant will then begin, which after a certain number of years will again provide us with a permanent supply of Bark.*

The expedients hit upon by certain writers on husbandry to shut the eyes of agriculturists and their own, to the light of science, and to make the comprehension of the laws of the nutrition of plants inaccessible to the mind and understanding, are truly most remarkable; and the history of agriculture will surely preserve the memory of them. To this day the farmer of the Wetterau justly regards the sale of his manure, not only as a disadvantage, but as a positive shame; it is an object of ambition with him to raise the largest possible amount of it on his fields. He has been taught that there is in manure a certain inconceivable and indefinable something which is to be met with in manure alone, and in no other matter;—that ash and gypsum are not food for plants, but serve, like the

* It is asserted that our high farmers "know the art of extracting from the same piece of land more grain than could be got from it in the seventeenth century. I doubt the correctness of this assertion, and think it quite within the limits of possibility that accurate statistical researches might prove the very reverse to be the case. Those who can look back a generation will probably remember, as I do, that large tracts of land which now are cultivated and bear produce, lay formerly waste (an advantage for which we are no doubt indebted to the rotation system). The question arises here whether, admitting the production to be larger now than formerly, the increase is not rather owing to the simple fact that the extent of producing surface is now considerably greater than it was. A distinguished American Economist, Carey, assures me that accurate statistical inquiries instituted in 1850 by the 'Times'' Commissioner have shown that England at that time produced actually 2,000,000 quarters of corn less than in 1774, according to Arthur Young. I will not venture to guarantee this fact, which, if true, would certainly look very significant.

whip of the carter to his lazy horse, to stimulate the activity of sluggish plants. Even up to the present time, they look upon the mineral constituents in guano and in bone earth, as not in the slightest degree contributing to the nutrition of plants, but simply as *auxiliary stimulants* applied to the soil for the purpose of promoting the production of stable dung.

The worshippers of manure, act in defence of their notions in a somewhat similar way to the Birkenfeld peasantry of last century, who grievously complained that government wanted to compel them to cultivate a foreign weed (clover). They told the officers in the plainest terms "to stick to their last, and concern themselves about things they had learned. As for husbandry, they (the peasants) were likely to know much more about it than all the margraves and overseers in the world." They did not wish to give the matter a single trial, and when ultimately compelled to sow the clover, they demanded, after a time, a magisterial inspection of their fields, and showed "that not a leaf of the clover had come up;" and no wonder; for it turned out at last, that the peasants had *boiled* the seed before putting it in the ground. In our day scientific principles are treated somewhat in a similar manner; the professors of modern agriculture boil them in their pot, and it is then openly shown that not a grain has come up. These gentlemen will on no account consent to see farmers freed from the compulsory rotation of crops; this they must understand much better than anybody does. But their own doctrine is barren, because it has no roots. Whatever good precepts their books contain, the agriculturist knows already, for these teachers derived their information from him; but such precepts as originate with themselves, inspire the farmer with no confidence, lead to no profitable ideas, do not increase his energies nor exalt his faculties.

If they would confine themselves to simply telling the agriculturist what this or that farmer has at any time done on this or that field;—that land requires to be well manured;—that guano and bone-earth constitute excellent manures, and that Chili-saltpetre, gypsum, and marl are also not to be despised,—surely no one would blame them for disseminating these truisms. But they have gone much further, and, in their blindness and shallowness have laid the axe to the very root of agricultural prosperity—and this can and must no longer be permitted.

They maintain and teach that in guano, Chili-saltpetre, and bone-earth, nitrogen is the only common constituent that is deserving of consideration, and that it is to this element alone that increased productiveness is to be attributed.

They teach and wish farmers to believe, that 10 to 12 pounds of the urine of cattle, which contains no phosphoric acid, will produce the same effect as 1 pound of guano, which is rich in phosphoric acid,—

simply because both substances contain the *same quantity of nitrogen.* They teach and maintain that the fertilising action of guano and of farm-yard manure depends upon the same cause, viz., their amount of nitrogen, and that guano must produce the same effect as farm-yard manure.

All this they maintain, without adducing a single fact in support of their assertions, or having once sought to show, by some unexceptionable instance, that the application of nitrogen by itself can make an exhausted field yield *for a number of years* the same crops of corn or other produce that are actually got from it by the application of farm-yard manure, guano, and bone-earth. That nitrogen could really produce such an effect everybody at all acquainted with the elementary principles of the nutrition of plants must know to be an actual impossibility.

But these teachers go even much beyond this. In No. 247 of the *Swabian Mercury*, of the 15th October, 1856, there is an article on Chili-saltpetre and its use, written by a Professor at one of the most renowned Agricultural Academies of Germany, in which the reader is told that "a hundredweight of Chili-saltpetre will produce the same effect as 75 to 80 cwts. of farm-yard manure, whilst a cwt. of guano will only be equivalent to 60 or 70 cwts. of the latter;—that a cwt. of Chili-saltpetre will produce about three cwts. of grain; that its action, however, is only perceptible the first year; that its price is 12 florins (20*s.*) per cwt., and that, accordingly, the corresponding value of a cwt. of farm-yard manure would be 9 krs. (3*d.*)"

This announcement may be said to be the very culminating point of the theory of our teachers of modern agriculture; it is evidently intended to induce the well-to-do peasant, and the small land-owner, who may be in want of manure, to buy Chili-saltpetre—a salt which contains none of the ash constituents of the cereals, but is composed simply of nitric acid and soda; one cwt. of which, we are assured, will produce three cwts. of grain. Its effect, it is true, lasts only one year, but it will, nevertheless, prove equivalent to 75 or 80 cwts. of farm-yard manure, the beneficial action of which on a field may still be observed after seven or eight years. The simple comparing of Chili-saltpetre to guano and farm-yard manure is, in itself, an offence against common sense; and the recommendation of that salt, at the expense of guano and farm-yard manure, is an injury inflicted on the property of thousands by an unprincipled or ignorant adviser.

A proceeding of the kind may be excusable in a commercial traveller soliciting orders for a speculator in Chili-saltpetre; but if we find that such notions are disseminated by teachers of agriculture and professors at agricultural institutions; if we see those teachers intent upon making the farmer believe, by means of a spurious array of figures, entirely inapplicable in the great majority of cases, that nitrogen possesses for him twice the value of phosphoric acid, five times that of potash, and twelve times that of phosphate of lime—it is time for all sensible men to unite and call these teachers to account. We may surely demand of them what is only right and fair, viz., that they simply prove the truth of their theories by a faithful statement of accurately observed and properly guaranteed facts.

Although it has, in these last years, been most plainly demonstrated to these men that their views and theories are founded in error, this has not brought conviction to the mind of a single individual. One after another has come forward with the vain and impotent attempt—not to adduce new and striking proofs in support of their doctrine—but to suggest doubts against the true import and bearing of the facts brought forward in refutation of their views. Not one of them has ever even dreamt of appealing, in support of the truth of his views, to his own numerous experiments and chemical analyses on which those views are based; because all of them know full well that their labour in this line will not bear the test of a rigorous scientific examination. In their distress they now turn for help to the same agriculturists whom they had, by these analyses, persuaded, that nitrogen was the only active agent in guano, bone-earth, and rape-dust, and appeal to them to bear witness that they have given them good advice, and that their theories have been borne out by practical experience; that a pound of ammonia has a practical value of twelve groschen, a pound of bone-earth of only one groschen. But the practical man, in truth, knows nothing of the action of ammonia or of nitric acid, or, at all events, nothing but from hearsay; for he has not been taught by the agricultural chemist that guano, bone-earth, and rape-dust are excellent manures, but the latter has, on the contrary, learned this fact from him, and has simply thrown in his own little hocus-pocus, that a few stray beams of the sunshine of their beneficial action might be reflected on him.

LETTER XI.

Ammonia is an element of food indispensable to Plants—Comparison of the action of Water and Ammonia—Ammonia is an element of food and a Solvent of Mineral Matters in the Soil—Ammonia alone, or its Salts, useless to Plants, without Mineral Food—Vast amount of Ammonia in Arable Soils—The "Nitrogen" theory of Manures—The error of attributing the chief value of a Manure to its Nitrogen—The reason why the quantity of Nitrogen in Guano and Excrements may be taken as a standard of their Agricultural value—Proper mode of Comparing the relative effects of Guano, Ground Bones, and Chili-saltpetre—The Loss of Fertilising matter in the Flesh and Grain carried to large towns; the constant loss of Phosphates in the Excrements of the inhabitants—The importation of Guano most inadequate to replace this loss—Superiority of Human Excrement over Guano as a Manure for Corn Fields—Tobacco, Potatoes, and Beet-root are more exhausting to a soil than Wheat—Injurious influence of extensive Cultivation of the Vine on the production of Corn and Wheat—Effect of the Subdivision of the Land.

As an element of food, ammonia is as indispensable to plants as carbonic acid; a brief consideration of the part which water plays in the nutrition of plants will best enable us to understand the fertilising action of ammonia in manure.

Water subserves a double purpose in vegetation; it supplies to the plant in one of its constituents an indispensable element, and serves besides to render mineral matter in the soil fit for absorption by the roots. Though the soil be ever so rich in the elements of food for plants, still the latter will not grow in hot weather, if there be a deficiency of moisture in the soil; for the moisture in the soil is the channel through which mineral food has to reach the interior of plants.

When there is a failure in the supply of mineral food, the leaves absorb neither carbonic acid nor ammonia from the air; and vegetation is brought to a stand-still, although the air contains more moisture in hot days than in cold,—this moisture being of no avail to the plant. With a deficiency of water in the ground, sunny and warm days, which under other circumstances would be the most favourable for growth, actually prove the most pernicious, particularly for summer plants, which have not yet had sufficient time to push their roots deep into soil where there still exists a supply of water that might convey food to them. In such cases barley grows barely a hand high and shoots into ear, and potatoes produce no tubers. One good shower at the *right time* changes this state of matters as if by magic. If the farmer could bring down rain upon his fields at the *right time*, as the gardener can water his flower-pots, all plants would give a maximum yield, pre-supposing of course, that there is a sufficient available supply of food; for if there be a deficiency of the latter in the soil, a corresponding diminution in the maximum yield must in consequence be expected. Plants therefore absorb carbon and nitrogen in proportion as the water conveys to them more of the *mineral constituents of the soil;* their growth is accelerated, and the weight of the crop increased.

It is exactly the same with ammonia. If we increase the quantity of ammonia in the air or in the soil, the plant finds at a *favourable juncture* a larger supply of this element of food than usual, and the consequence is, that a correspondingly larger amount of the mineral elements of food is rendered available. As the leaves of a plant can daily come in contact with only a certain volume of air, they can of course take up from it no more ammonia and carbonic acid than this volume of air contains; the absorption of these substances and the increase of the plant consequent thereon require accordingly a *given* time. If a plant every day absorb an equal amount of these elements of food, it will receive of course twice as much in two days as in one.

If a plant on favourable days received twice or four times the usual supply of mineral food, the surplus must remain inactive until the leaves shall have taken up from the air sufficient carbonic acid and ammonia to combine with these mineral elements in the formation of constituent parts of the frame of the plant. None of the elements of food will act without the presence and co-operation of the others. If, accordingly, we increase the amount of ammonia in the soil, or in the air (of carbonic acid, there is generally no deficiency), the development of the plant will, the other conditions of its growth being equal, be considerably quickened; in other words, the plant will grow in bulk and substance much faster than under ordinary circumstances. Familiar illustrations of this may be seen every day in hot-beds. *Had the mineral elements of food not been present in the plant and available for its nutrition,* the ammonia would not have had the slightest effect on the increase of the bulk of the plant.

It need then excite no wonder that the application of guano to a field should so largely increase the yield of corn; for guano contains not only the mineral elements which a soil must possess to produce corn, but also in the ammonia an indispensable element of food, which serves to quicken their action and to shorten the time required for their assimilation. On many fields the ammonia in the guano may, if the weather prove propitious, possibly effect the assimilation of double the ordinary quantity of these mineral constituents, and thus render the amount of produce yielded in one year equal to what would have been otherwise obtained in two years by these mineral matters alone.

It is clear also that ammonia used by itself in a soil containing a sufficient supply of the elements required for the production of a corn crop, must exert a favourable action on the increase of the produce. But as in the large crop reaped, there is now removed from the field a greater proportion of the conditions upon the presence of which the efficacy of the ammonia depended,—if the application of ammonia be continued, and no restitution be made to the soil of the mineral elements removed,—then the yield must necessarily diminish, in the years following, in the same proportion as it was higher in the first and second years.

In one word—ammonia is a most useful manure when it is accompanied by the mineral elements which render it active, or when it finds in the soil those conditions which are necessary to its efficacy; it is absolutely of no value to the farmer if he neglect to restore or supply these elements.

In a soil sufficiently rich in nitrogen, but poor in certain mineral elements indispensable to the growth of many plants, the application of ammonia, or of its salts, is at any rate useless, and often absolutely injurious. In such a soil, which simply is deficient in a proper supply of phosphoric acid, a dose of that substance, unaccompanied by ammonia, will produce the same fertilising effect as guano, only, probably, in a higher degree. The General Committee of the Agricultural Society of Bavaria, at Schleissheim, caused a portion of one of the poorest worn-out fields in the vicinity of Munich to be manured, by way of experiment, with acid phosphate of lime (phosphorite); the result was, a crop of summer wheat double in amount to that yielded by an equal portion of the same field unmanured. Had guano been the manure used in this case, the crop would most indubitably have far exceeded that reaped from the unmanured plot, and a supporter of the so-called nitrogen theory would as unquestionably have ascribed the effect to the ammonia contained in the guano, which could not possibly have had anything to do with it, in the foregoing experiment. The same manure, viz., acid phosphate of lime, has been applied with equal success elsewhere, without any co-operation of ammonia, and frequently larger crops of grain have been obtained than from the use of guano; it is, therefore, quite evident, that for a field in that condition ammonia is almost quite valueless. The explanation also of this fact has been ascertained by chemical examination: it has been found that most fields contain, within a depth of from ten to twelve inches, a hundred, five hundred, often even a thousand times more ammonia in a similar form, than is present in rotten farm-yard manure, in bones, or rape-dust; it is, then, quite clear, that where the soil happens to be deficient in even one of the indispensable mineral elements of food, the existing great store of ammonia will be of no avail in increasing the productiveness of the land.

In the vicinity of Magdeburg, the residue left after the distillation of beetroot-molasses, which contains the soluble salts of the beetroot, (no salts of ammonia) has, of late, been used as a manure, and I have been assured that fields treated with it have yielded, several years in succession, most abundant crops of rape, beet, &c.

For each field there exists some effective agent of this kind; but it will never be found, if we rest contented with simply chanting the praises of ammonia. As we have seen, in Letter II, the soil never contains free ammonia; and in the rotten farm-yard manure the greater proportion of the liberated ammonia enters into chemical combination with the humus-constituents of the dung—being taken up by them directly from the liquid portion, which accounts for the fact that the latter is comparatively so poor in that ingredient.

Free ammonia, or an ammoniacal salt, put upon a field, immediately forms with the constituents of the surface soil a combination from which the plant subsequently derives this element of food. In this way, the ammonia conveyed to the soil in rain goes on accumulating; it would, therefore, be an act of common sense to expend no money in the purchase of this dearest of all manuring agents, before first making sure that phosphate of lime, either alone, or in conjunction with sulphuric acid, or ash, or the two together, or lime, has failed to stimulate the productiveness of the field, in the first place, for underground plants (turnips, potatoes, &c.), and for the subsequent crop of cereals. It is only after making such trials, that the employment of ammonia can be justified.

Let it not be thought, however, that the notion of the professors and advocates of the so-called nitrogen theory, which makes the nitrogen, or the ammonia, the principal agent in manures, and the pivot upon which all agricultural production turns, is purely imaginary and absolutely baseless. This notion has, on the contrary, arisen from a very pardonable error, formerly but too common in science, and which is still occasionally met with at the present day.

It is quite true that *the agricultural value*, for the production of grain, of the *various sorts of guano*, and of all *excrements of animals*, may be accurately determined by the proportion of nitrogen or ammonia contained in them. The mistake made in the matter essentially lies in this, that, taking their stand upon these facts, which are perfectly true in themselves, people attributed the action of these manures to the nitrogen, which, indeed, performs a part in this action, but, in most cases, only a subordinate one. This is the same error which Lavoisier and Davy committed in designating, the one, oxygen, the other, hydrogen, as the acid-generating principle.

To comprehend this fact, we must bear in mind the composition of grain, of flesh, and of those constituent parts of plants which serve to form blood, and which have a composition similar to that of flesh. All these matters contain the combustible and incombustible constituents of the blood. A person living on bread receives into his organism the ash-constituents of the grain which has furnished the flour for the bread; his excrements contain the ash-constituents of the same grain. Out of the elements of the bread flesh is made, and the excrements of men or animals living on flesh are in their elements identical with those of men or animals living on bread or seeds. Bread, flesh, and blood, contain an ingredient rich in nitrogen, which, taken in the food, serves to sustain the vital functions, or the change of matter in the body: the *nitrogen* of this ingredient is again every day eliminated in the urine and fæces, in the same quantity in which it has been partaken of in the food.

The excrements of men and of animals, therefore, not only contain the ash-constituents of the seeds, the flesh and the component parts of the roots, tubers, herbs, &c., that have served to form blood and flesh in the animal organism, but they also contain the far greater proportion of the nitrogen of these seeds, and of the blood and flesh-forming elements. As we have already had occasion to observe, it has been demonstrated by the most accurate chemical analysis,* that there is a fixed and invariable ratio between the amount of nitrogen in seeds and the quantity of phosphoric acid or of phosphates contained in them (between the nitrogen and the ash-constituents of the seed); so that, if we know the proportion of nitrogen in seeds, we can, from this, calculate the amount of phosphoric acid, or of phosphates, present in them.

Now, in the solid and liquid excrements, these several constituents are naturally contained in the same, or very nearly the same, fixed relative proportions as in the seeds. The solid and fluid excrements

* See "Results of agricultural and chemico-agricultural experiments conducted by the General Committee of the Agricultural Society of Bavaria at Munich; Cotta's Literary and Art Institution, 1857."

together contain the nitrogen and the ash-constituents of the bread, flesh, &c. of the consumed food; and we can therefore readily understand how we might, by ascertaining the amount of nitrogen in an excrement, estimate, in an analogous way, in a tolerably exact manner, the quantity of mineral constituents of seeds or of flesh present in it.

In point of fact, the original relative proportion between the nitrogen and the ash-constituents in excrements is altered. The nitrogen is converted in the putrefactive process into ammonia, a portion of which is lost by evaporation; and even before the process of decomposition has set in, part of the nitrogen present is carried off, together with the most efficacious soluble salts, in the liquids which ooze away. This latter loss, however, might be guarded against, and ought to be so, by the use of absorbing earths. The proportion of nitrogen in the contents of latrines, or in poudrette, in farm-yard manure, and in guano, affords, therefore, no proper standard of their agricultural value, which depends upon the ash-constituents of seeds contained in them; but of two sorts of guano analysed, we can, with tolerable certainty, regard that one as the purest in which is found the largest per centage of ammonia; any adulteration of the article lessens that proportion. The same remark applies to poudrette which very often contains as much as fifty per cent. of sand (sweepings) and other extraneous matter unfit for the nutrition of plants;

and probably, also, this holds good for farm-yard manure.

It is therefore by no means absurd, but quite correct, to say, that the value of the several sorts of guano, of poudrette, and of farm-yard manure, bears a certain relation to their amount of nitrogen. But the inference drawn from this fact, that the agricultural value of these manures, and their beneficial action upon the soil, are entirely dependent upon this relative proportion of nitrogen, and that, accordingly, ammonia and its salts might be used with equal success in cultivation, in lieu of them, is over-hasty, and entirely devoid of all foundation. Were a farmer, by the advice of the apostles of this so-called nitrogen theory, mad enough to manure his fields, even for ten years only, consecutively with salts of ammonia, or with Chili-saltpetre, and were he, confidently relying upon the perfect fitness of these salts, to replace farm-yard manure, poudrette, and guano, to sell off from his fields the entire produce, he would assuredly be a beggar at the end of this period. If all agriculturists in Germany were to agree never to return to their fields the mineral constituents of their manure-heaps, because their teachers have assured them that the soil is inexhaustible in these elements, half the population of Germany would be starved to death before the end of ten years.

It is, altogether, one of the most discouraging signs in agriculture, that frequently the best-informed men will, in judging of the value of a manure, and of its effect, act as if they were devoid of judgment and common sense.

In comparing the action of guano, bone-earth, and Chili-saltpetre, it will not do to draw a line under the calculation at the time of harvest, or after the expiration of a year, and argue that guano or Chili-saltpetre is a better manure than bone-earth, because so many more pounds of corn have been yielded by the use of the former than by the latter. Common sense tells us that *the effect of individual manures must be judged of by the condition in which they leave the field.*

It is very evident that if after a large crop which has been obtained by the use of Chili-saltpetre in one year, the soil has required in the following year a double quantity of manure to yield the same amount of produce, much money has in such a case been laid out to no purpose; and I greatly fear if an exact reckoning be kept of the produce of their fields for a series of years, and also of the expenditure of manure, in addition to Chili-saltpetre, agriculturists will find that for the money spent in the latter agent, they have received scarcely any other return than a very beautiful deep green colour of their crops in the first period of their vegetation.

A comparison of the action of guano with Chili-saltpetre, and bone-earth (or phosphorite), can be made only after several years. If guano applied to a plot of land very perceptibly increases the potato crop in the second, and the clover crop in the fourth year, whilst a dose of Chili-saltpetre of the same pecuniary value is not followed by a similar increase, those after-effects must be taken into account if we would avoid drawing a superficial estimate of the value of the two substances.

When the agriculturist who makes comparative experiments with guano and other manures, and appears to have obtained in the first year from the guano the most favourable results, points to its greater proportion of nitrogen and draws the conclusion that these greater effects have been directly due to this element, we may well ask him why he has not also made a comparative experiment, upon an equal piece of land, with a similar quantity of ammonia to that which is contained in guano, and in this way obtained a standard by which to measure the effect of ammonia in guano.

But a proceeding of this kind has never yet been thought of by any one of these experimenters, who also keep from the farmer the fact proved by the most extended and accurate experiments of Lawes, Kuhlmann, and others, that *a pound* of ammonia in guano produces *five times* the effect of the same quantity applied in the form of a salt of ammonia. (The action of pure ammonia is altogether unknown.) Now it is quite clear that the more powerful effect of the ammonia in the guano is simply owing to the presence and co-operation of other matters; and when the combined action of these latter and the ammonia is found to be four times greater than that of the ammonia alone, then wherever it is thought desirable or requisite to use ammonia it will evidently be a wise step to provide for the presence of these matters, that in such cases likewise the action of the ammonia may be increased five-fold.

When an agricultural chemist (Dr. Stöckhardt) asserts that "he chiefly owes to guano his positive conviction of the great importance of nitrogen compounds that are easily assimilated, and is thus indirectly indebted to it for the most glorious acquisition achieved by his labours in the field of agricultural chemistry," the latter alone is true thus far, viz., that if it had not been for guano the world would scarcely have heard of the labour of this individual in the field of agricultural chemistry. A man of science ought not to cling to a cork buoy to enable him to swim; and if it keeps him afloat he ought to be grateful for this, but not proud of it. Guano requires no cork buoy; it would assuredly have made its way as railways have done, as indeed it has done in other countries, to a much greater extent than with us, without requiring the least aid at the hands of the chemist. Things which bring in money will always make their own way.

When agricultural chemists maintain that ammonia or its salts are the universal means for the growth of wheat, or acid phosphate of lime for that of the turnip tribe—they simply show thereby that they do not understand the essential principles of the science of agriculture.

The corn-growing agriculturist removes from a hectare ($2\frac{1}{2}$ acres) of his wheat field, in an average crop of corn of 2000 kilos, 70lbs of the mineral constituents of the grain; of which 34 pounds consist of phosphoric acid and 21 pounds of potash, and he supplies these to the consumers in large towns. In an ox of 550lbs weight, the town receives 183lbs of bones, containing nearly 120lbs of phosphate of lime; in the flesh, hide, and other parts of the animal 15lbs of phosphates, which are identical with the constituents of the seeds of rye.*

The annual fluid and solid excrements of a million inhabitants of large cities (men, women, and children), weigh in the dry pulverulent state 45 million pounds; in which are contained 10,300,000 pounds of mineral substances, mostly ash-constituents of bread and meat (not including five million pounds weight of bones of the slaughtered cattle, &c., nor the mineral substances in the evacuation of horses, &c.). These human excrements alone contain 4,580,000 pounds of phosphates.

* In the city of Munich there were slaughtered in the year 1855-56, 16,301 heads of cattle, which, at an average of five cwt., weighed 8,150,500 lbs.; besides which there were slaughtered 66,186 calves, swine, and sheep, giving, at an average of 70 lbs. each, 5,675,020 lbs.—not reckoning the cattle slaughtered, at the free butcheries, by the keepers of taverns, and eating-houses.

This enormous drain of these matters from the land to towns, has been going on for centuries, and is still going on year after year, without any part of the mineral elements thus removed from the land ever being restored to it; a very small proportion only is turned to account in the garden and fields in the more immediate vicinity of towns.

It is perfectly absurd to suppose that the loss of these matters which are so essential to the productiveness of a soil should have had no influence upon the amount of its produce. Indeed, even the most prejudiced agriculturist cannot help feeling some alarm at the enormous extent of the loss, if he reflects upon the amazing increase in the yield of corn and flesh which has taken place since farmers began by the use of guano, to restore to the despoiled fields only a very small fraction of the corn and flesh constituents carried away from them. I have already remarked upon the identity of the constituent elements of guano with those of human excrements. In a series of very instructive experiments made expressly for the purpose in six different parts of Saxony, it was found that a field manured with guano gave in three successive years for every 10 pounds of guano used, 15 pounds of wheat grain, 40 pounds of potatoes, and 28 pounds of clover more than was reaped from an unmanured plot of land of the same kind and extent. According to the condition of the field the surplus thus reaped varies from 10 to 20, and in England up to 22 and even

28 pounds of corn, for every 10 pounds of guano used.*

* "In the United States distances of hundreds and thousands of miles separate the places where the corn is grown from the markets; the consequence of this may be seen in the fact that the soil is almost everywhere exhausted, and that the prosperity of the country is declining, instead of increasing.

"The rate at which this decline is progressing, has lately been shown by a distinguished agriculturist, from whom we learn: 'That the phosphoric acid and the potash taken annually away from the fields, without any compensation worth mentioning being made to them, are at the current price of the market worth twenty million dollars; that the ash-constituent of 600,000,000 bushels of corn are annually carried away from the land without any material restoration of them; that the entire annual waste of the mineral constituents of corn is equal to 1,500,000,000 bushels of corn.'

"To suppose, says the author of these estimates, that this state of things could last, and we as a nation increase in wealth, is simply ridiculous. It is only a question of time, and time will solve the problem in a way not to be mistaken. What we lose with our system of destroying the soil, and wasting its resources, is the very essence of our existence.

"Our land has not yet grown feeble from this loss of its life-blood; but the hour is indicated when, should the present system be persisted in, the last throb of the heart of the nation will cease,—when America, Greece, and Rome will stand side by side amidst the ruins of the past.

"The national economic question is not how much we are able to produce, but how much of our annual produce is returned to the soil. Labour spent in the spoliation of the soil is worse than labour thrown away. In the latter case the loss falls upon the present generation, in the former, poverty is the inheritance of posterity.

"Extravagance, Mr. President, is a crime which finds its punishment in the natural, moral, and political decay to which I have invited your attention. Its effects may be seen in the fact that in New York, where the average yield of wheat was from 25 to 30 bushels 80 years ago, it is now only 12 bushels; Indian Corn gives only 25 bushels. In Ohio, a State which 80 years ago was still a wilderness, the average yield of wheat is under 12 bushels, and is decreasing instead of increasing. In Virginia there is an extensive tract of land, once the richest in the State, which now produces only an average yield of wheat of less than seven bushels; whilst in North Carolina land is cultivated which produces little more than the same yield of Indian corn.

"In Virginia and Kentucky tobacco was grown until the soil was completely exhausted, and had to be abandoned; and in the cotton districts we meet with a state of exhaustion unexampled in the world, It may therefore be safely assumed that the importation of a million cwt. of guano is equivalent to an increased production of 2,000,000 cwt. of corn which could not have been raised by the existing stock of home-made manure alone; this latter performs its own part in increasing the produce exactly the same as if the guano had not co-operated with it.

In the flesh and the produce of the field we have for centuries supplied to the large towns the constituent elements of guano, and have never brought this guano back again; and we now send vessels to Chili, Peru, and Africa for this substance. For every 45 million pounds of guano we pay the foreigner 3 million florins. By the *exportation of these elements* our fields have lost in productiveness; were it not so, how could it have been conceivable or possible for us to have been able to raise their fertility by the *importation* of these elements? Where a field is truly in *prime condition, no manuring agent* can possibly increase its productiveness; the surplus yield attained by the use of guano is therefore usually much less on well than on ill managed estates. Whilst in the case of the former it no longer gives a *remunerative* return so soon as it

for the shortness of the time in which it has been brought about. The growers of cotton and tobacco live upon their capital; in the produce of their fields they sell their fruitful soil at so low a price that for every dollar they receive they destroy to the value of five dollars."

(Letters to the President on the Foreign and Domestic Policy of the Union, and the effects as exhibited in the condition of the people and the State. By H. C. Carey. Philadelphia. J. B. Lippincolt & Co. 1858. Tenth letter, p. 54.)

rises somewhat higher in price; the bad manager will however continue, and justly so, to praise it as a profitable agent.

In the year 1855-1856 above 10 million cwt. of guano were imported, of which the greater portion remained in England. In the course of half a century above 60 million cwt. of bones have been imported into that country; yet all this mass of manure is not worth mentioning when considered in relation to the arable surface of Great Britain, and is but as a drop when compared to the sea of human excrements carried by the rivers to the ocean.

The loss annually sustained by the land can only be very partially remedied by the purchase of foreign manures. In the year 1852, the consumption of guano in Saxony amounted in the districts of Dresden, Leipzig, Zwickau and Bautzen to 60,000 cwt., which gives 16·9 cwt. for every 400 acres of land (= 55·3 hectares), or $4\frac{1}{5}$ pound per acre (3·82 kilos per hectare). In these 3·82 kilos of guano (of the better sorts) there are contained not above $1\frac{1}{3}$ kilo of the mineral constituents of seeds; whereas there are annually removed from the fields 35 kilos per acre in the corn crop alone. If therefore Saxony imports in a year 1,428,000 cwt. of guano containing 35 per cent. of ash-constituents (for about $5\frac{1}{2}$ million thalers), this is no more than has been taken away from all the Saxon fields in a single corn crop.

No more importance need be attached to these figures than they deserve. They are sufficiently precise to show that our fields would be incalculably more fertile; that we might now produce infinitely more food for man upon the same arable area; that we should not be forced to sacrifice one-half of it to cattle—if our ancestors had only prudently and carefully brought back from the towns and restored to their fields the guano carried away from them in the produce.

There is not to be found among the industrial classes a set of men more intent upon immediate and temporary gain than the common peasants, and less capable of making correct calculations in an industrial point of view; although one would suspect the very reverse to be the case.

The *prudent* agriculturist who purchases potatoes from the peasants in his neighbourhood, for the purpose of distilling alcohol from them, or rape seed for its oil, *knows* that every two acre crop of potatoes which the peasant sells to him, will in the residuary matter yield him three crops of rye (seed), or a full crop of rape. He knows that every cwt. of rape in oil-cake is worth two cwt. of wheat grain to him;—and in establishing a distillery or oil mill, he takes into due account the advantages derived from this addition to the conditions of the fertility of his land.

The peasant from whom he purchases the potatoes or rape-seed *knows* that the buyer looks upon this additional supply of fertilising matter from the residues as *important*, but he himself considers it of *no value* to his land. It never occurs to him that it would be a prudent act to retain the manure constituents for his own fields at the sacrifice of a portion of the money received for his produce.

The seller, if he is also a farmer, should sell only the oil of his rape seed, and only the starch of his potatoes,—for in this way alone can a proper circulation be maintained.

But the agriculturist sells not only corn, but also potatoes, rape-seed, beetroot (to the sugar boiler), tobacco, hemp, flax, madder, poppy, and wine.

Whilst the corn and flesh growing agriculturist exports in the produce of his fields only phosphoric acid, alkalies, and alkaline earths, he retains on the land the elements of the straw and of the fodder plants which pass in the rotation of his crops from one field to another. The deep rooting clover and the plants of the turnip tribe take them up from the sub-soil, and in the form of farm-yard manure, continually accumulate them in the surface soil. The manure and the surface soil receive every year an additional supply of soluble silicic acid, alkalies, and salts with alkaline bases; but the proportion of phosphates in them is constantly on the decrease.

Hence it will be readily understood why the use of these manuring agents—viz., soluble silicic acid, potash, and potash salts—will not have the slightest beneficial effect on the fields of the corn and flesh growing agriculturist; for his fields contain already an excess of these agents which remain inactive from the want of phosphates. We can further understand why the corn and flesh growing agriculturist should regard in the *most important light* the supply of phosphates, of guano and of human excrements; and *hold the other elements of food for plants as almost of no value.*

On such fields, simple manuring with human excrements, with or without the co-operation of farm-yard manure, may produce large corn crops for an infinite number of years in succession; but the continued use of guano exhausts also this land. The excrements of man contain the *full complement* of mineral elements removed in grain and flesh; but in guano there is *wanting* a certain quantity of potash to replace fully these ash constituents. Hence on soils poor in potash (on lime and sandy soils), the action of guano after a certain time perceptibly diminishes, and its efficiency is then restored by the addition of wood ashes, rich in potash.

It is a very different matter with the grower of potatoes and beetroot, who sells his produce to the distiller or to the sugar maker.

In the average produce of three hectares of land, the potato grower sells and takes away from the soil the grain constituents of four wheat crops, and upwards of 600 pounds of potash in addition.

In the produce of three hectares of land the beetroot grower sells and takes away from the soil the grain constituents of four wheat crops, and 10 *cwt. of potash* besides. The single sugar manufactory at Waghäusel supplies to commerce every year 200,000 pounds of salts of potash obtained from the residue of the molasses, and which were originally derived from the beetroot fields of Baden.

It is evident that, in the cultivation of potatoes and beetroot, two causes of exhaustion operate on the fields: these kinds of produce withdraw from the soil at each harvest, one-third more phosphates than a wheat crop, and in addition to these an immense amount of potash and its salts. Beetroot and potato fields, abounding in potash, may therefore have their produce augmented by simply manuring with guano or superphosphate of lime; but as guano and bone manure do not replace the potash removed in the produce, the ultimate result is, that after a certain number of years the land is found to be so much the more thoroughly exhausted. On other potato- and beetroot fields poor in alkaline elements, farm-yard manure, which abounds in alkalies, answers better than guano.

The growers of marketable plants are in the most unfavourable position as regards the restoration of the mineral elements annually carried off from their fields by these plants. A tobacco planter takes away in the tobacco leaves an immense amount of mineral elements (in clover-hay, for instance, not above 10 per cent., in tobacco leaves, from 18 to 24 per cent.).

If he happens to be in possession of fields for green crops which supply him with manure for the tobacco plants, he is in the same position as the agriculturist who sells and alienates from his land the clover, turnips, &c. grown thereon; that is to say, in the course of a few years he is sure to reach a point when his land will no longer produce tobacco; and driven to procure elsewhere a supply of the indispensable mineral elements, he now turns to his grain and flesh producing neighbours, and purchases from them at high prices their *clover and turnips in the shape of farm-yard manure.* Now, if this neighbour, over estimating the quantity of farm-yard manure in his possession, disposes of a portion of it to the tobacco grower, he generally soon perceives his error, by the diminution of his crops. He is first of all made aware that manure cannot be produced at will, and that the counsel given to him to "grow more provender for his cattle, as corn crops will then be sure to follow in due course," is of no use to him; he finds that it was his manure that for seven or perhaps ten harvests has given him the sixth or seventh grain which constituted his entire profit, and that in parting with his manure he has actually sold for a song his profits for many years to come. Made wise by experience, he now sells no more farm-yard manure.

The tobacco planter, finding he can no longer procure manure from his neighbour, now applies to grain and flesh producers living farther off, who have yet to find out by experience what the neighbour has already discovered; and thus the sphere of his foraging operations in search of manure grows wider and wider every year, until he finds himself ultimately constrained to procure his manure from towns, and to supply by other means the elements in which the town manure is deficient.

The same state of matters we find also in countries where the vine is extensively cultivated. Vineyards are generally planted on slopes, and are destitute of arable surface soil; the soil is, comparatively speaking, infinitely poorer in the elements of food for plants, than is the case with fields situated in plains. Vineyards produce no manure; the wanting mineral elements of food are supplied, within certain limits, from the neighbouring corn- and pasture-fields; and the proprietors of these, if they have an opportunity, in their turn pillage the neighbouring woods.

By deep digging the vine-dresser seeks to fit his poor soil for the reception of the deep-rooting vine; and by the occasional cultivation of lucerne and clover, he endeavours to accumulate by their means in the surface soil, the mineral elements in which it is deficient. He conveys to his vineyard arable soil from fields which he has acquired for that special purpose, and also applies as manure the *débris* of disintegrated rocks abounding in alkaline matter.

The culture of the vine exercises accordingly on the production of grain and flesh an adverse influence similar to that caused by the planting of tobacco and other produce grown for sale.

The producer of corn and flesh, according to the prevailing system, robs his own land; the producer of wine and marketable plants despoils in his turn the corn and flesh producer; and lastly, large towns, like bottomless pits, gradually swallow up the conditions of fertility of the greatest countries.

In this way the vine growers and tobacco planters of the Palatinate and of the Bergstrasse exhausted the fields of the Hessian and Badish Odenwald, and completed the ruin of the already impoverished and encumbered peasant who could not resist the tempting sound of the silver offered him for his manure.

In the same way the sewers of the immense metropolis of the Ancient World, engulfed in the course of centuries, the prosperity of the Roman peasant; and when the fields of the latter would no longer yield the means of feeding her population, these same sewers devoured the wealth of Sicily, Sardinia, and the fertile lands on the coast of Africa.

The fertility of the land has remained unimpaired for centuries, in such parts only where an agricultural population dwells crowded together on a comparatively small area, and where the tradesman and craftsman inhabiting the small towns thinly scattered over that area, till their own little plots of ground with the assistance of their journeymen.

When there are living on a (German) square mile of land in that position, 2000 to 3000 people, no exportation of grain or flesh is possible, for the produce of the fields is only just sufficient to feed the population; a surplus for exportation either never or very seldom exists. The fertility of such a tract of land is kept up unimpaired by the regular circulation of the conditions on which this fertility depends. All the mineral constituents of the produce consumed are brought back without diminution to the fields from which they were taken. None of these elements are ever lost; for everybody knows the inevitable consequences, and is therefore careful to do his best to collect and preserve them.

Now, supposing this same land falls into the hands of ten great proprietors, the pillage and plunder system then takes the place of the system of restitution and compensation. The petty proprietor almost entirely restores to the field what he takes from it; the large proprietor, on the other hand, sends his grain and flesh for sale to the great centres of consumption, and accordingly loses the conditions for their reproduction. After a number of years the land placed in this position, will be turned into a desert waste like the Roman Campagna.

This is the natural cause of the impoverishment of lands by cultivation; there is no other; the teachers of modern agriculture alone do not recognise this cause, and are with all their power intent upon accelerating the ruin of German agriculture, and making it irretrievable. Fertile fields—so these teachers tell us—are inexhaustible in the conditions of fertility; they only require the whip to stimulate them into action. Good fortune kindly sent guano to rescue them in their utmost need,—the result of their own teaching; but in *their* fatal hands this blessing is actually turned into an instrument for impoverishing the land in the course of time still more completely. But guano will ultimately also come to an end, and what is to be done then?

"We have not yet come to that pass," we hear those exclaim, whose fields are still fertile and yield abundant crops; "we are not yet come to that pass," said also a certain robber who was admonished to lead a better life, until one fine morning he found the hangman's rope around his neck. "To that pass" it will also assuredly come at last with agriculturists. Their system may be based on agricultural experience, but it is certainly devoid of all foundation in science.

LETTER XII.

Modern Agriculture has no history—The reason of this—The history of Roman Agriculture shows the existence of the spoliation system at that period—The works of Cato, Virgil, Varro, and Pliny inculcate, two thousand years ago, the same precepts that are now taught by many teachers of agriculture—Quotations from these writers, to show their opinions on the exhaustion of the ground; on the different kinds of soils, and the modes of improving them; on the selection of plants for the soils which are suitable for them; on fallowing; on the cultivation of green crops for manures; on the different kinds of manure and their relative values, and modes of managing them—The various precepts inculcated of old only hastened the ruin of Roman agriculture.

THE history of mankind, says *Thaer*, is also the history of agriculture. No saying can be further from the truth than this. All our departments of industry having any connection with the natural sciences have a history: modern agriculture alone has none; for it is a thing of to-day, or, at the most, but of yesterday. What occurred a week ago, it knows not; and if it is acquainted with it, such knowledge does not make the agriculturist any wiser.

Facts by the million cannot be bequeathed; but scientific principles which are expressions for these facts, may be so, because they are immutable in their nature.

Agriculture is, of all industrial pursuits, the richest in *facts*, and the poorest in their comprehension.

Facts are like *grains of sand* which are moved by the wind, but principles are these same grains cemented into *rocks.* A *fact* simply tells us of its existence, but *experience* ought to inform us *why* it exists.

Science is conservative in her nature, not destructive. She does not reject the truths discovered by practice, but receives them; they are never disputed by her, but are examined and receive from her their proper import and further application. Science, therefore, can produce no revolution in practice; but she leads the way to a series of progressive developments, which are evolved in natural sequence from each other.

Modern agriculture has methods and working systems, but it is altogether deficient in fixed principles and positive knowledge. After so many thousand years, even our *best-informed* and *most-experienced* agriculturists do not yet *know* what kind of manure will *answer best*, or under what circumstances *fresh* manure ought to be used in preference to *old*, or *vice versâ !*

Modern agriculture has, up to this time, no connection with the history of the development of man; that history is the mirror which reflects not only his errors and failures, but also his onward progress. But modern agriculture rejects the idea of ever being in *error*, and therefore she knows nothing of *progress.*

If the history of the development and progress of the human race really found a place in the study of modern agriculture, or if teachers of that pursuit would only take the trouble to make themselves acquainted with the pages of that history, our agriculturists would know that, two thousand years ago, the most enlightened and most eminent men of ancient Rome already found the cultivation of the soil beset by the same difficulties which threaten it to-day; and that the same system of "high farming" which our modern teachers now recommend as the best, was then tried, and found wanting.

The following statements, taken from the writings of Columella, Cato, Virgil, Varro, and Pliny, are calculated to enlighten the agriculturist as to the actual point of "progress" to which he has attained in the practice of his pursuit; and to show him that his modern teacher, after all, inculcates nothing that was not known to the world equally well, and often even much better, two thousand years ago. Reading the twelve books of Columella, after a perusal of our modern manuals of practical agriculture, is just like stepping from an arid and barren desert into a beautiful garden—so fresh and charming does everything appear.

In his preface addressed to Publius Silvinus, Columella says: "The Magnates of the state are in the habit of complaining of the sterility of the land, or of the unsettled state of the weather, which has now for a long time exerted an unfavourable influence on the growth of agricultural produce; others are of opinion that the soil has been exhausted by the over-productiveness of former years. But," he continues, "no one gifted with common sense, will ever permit himself to be persuaded that our earth has grown old, as man grows old. The sterility of our fields is to be imputed to our own doings, because we hand over the cultivation of them to the unreasoning management of ignorant and unskilful slaves.

"The agriculturist requires one kind of knowledge, the herdsman another. The former ought to know what produce will answer best for his land; the latter must understand the most remunerative way of breeding cattle. Now, as the two pursuits are most intimately connected with each other, inasmuch as it is much more advantageous to use the provender grown on the field for home consumption, than to sell it; and as manuring mainly contributes to make a field fertile, and cattle are principally kept for the production of manure, therefore every body who owns a farm must not only possess a knowledge of agriculture, but also of pasturage, and of the process of stall-feeding."—(Columella).

"Wherein does a good system of agriculture consist? In the first place, in thorough ploughing; in the second place, in thorough ploughing; and, in the third place, in manuring."—(Cato).

"Colour is no reliable sign of the good quality of a soil. For as the strongest cattle exhibit an almost infinite variety of colour, so is also the best land of many and divers colours."—(Columella).

"There are many different sorts of soil; such as chalky, sandy, clayey, &c. One soil is moist, another dry, or moderately so; there are rich soils and poor soils, light soils and heavy soils. By the intermixture of these an infinite variety is created. A stiff clay soil may be improved by the addition of sand or marl; a sandy soil, by the addition of clay."—(Pliny, Pallad. Col.).

"Superfluous moisture must be drawn off by ditches, either open or covered; in a chalky and stiff ground open ditches are preferable. Open ditches must be wider at the top than at the bottom; if they are of the same width throughout, the sides are undermined by water, and the falling earth fills up the ditch. Covered ditches are dug to the depth of three feet, half filled with small stones or coarse gravel, and the earth dug out is then thrown over the top and levelled. If neither gravel nor stones are to be got, then as many bundles of brushwood are thrown in as the narrow ditch will hold, and the whole is covered with earth. At the openings of the ditch, two stones are placed upright, as pillars, to support a third, like a small bridge; this keeps the ditch open."—(Col.)

"A soil to be fertile must, above all things, be light and friable, and this condition we seek to bring about by the operation of ploughing."—(Virgil).

"Ploughing the land simply means rendering the earth porous and friable, which most tends to increase its productiveness."—(Cato).

"The ancient Romans held, that a field which required harrowing could not have been well ploughed." —(Columella).

"A heavy soil should be turned up in autumn, and ploughed three times, and the furrows be multiplied and drawn so closely together, that it may be barely possible to distinguish from which side the plough has proceeded; for by these means weeds are thoroughly rooted out. Fallow land must be ploughed until it is almost reduced to powder. The owner of a farm should often ascertain for himself whether it is properly ploughed. For this purpose, he need simply thrust a staff through the furrows (the Romans laid out their fields in broad undulating ridges, as may still be seen at the present day in the neighbourhood of Nuremberg; only the Roman ridges were much broader); if the staff passes through unresisted, it is a sure sign that the soil has been properly ploughed. Care must be taken to break clods of earth. Fields should be ploughed when neither too dry nor too wet; if the soil is too hard, the plough will not penetrate, or it will simply tear off large clods. Even the best soil is unfruitful in its deeper layers, and the large lumps of earth torn up by the plough bring part of this subsoil to the top, which tends to deteriorate the arable surface soil. Always select for your fields those plants that may be best suited to their positions"

(Cato); "for all plants will not thrive equally well in all sorts of soils."—(Varro). "Some plants require a dry soil, others thrive best in moist ground."—(Col.). "Naturally moist ground answers best for pasturage." —(Cato). "Hay grown on naturally moist ground is better than where its production has to be stimulated by irrigation. A meadow plot in a plain must have a slight fall, that rain and other water may not gather on it in pools, but gently flow off."—(Col.). The seeds intended for sowing should be picked out by hand, and pulse be previously soaked in saltpetre water:—

> "Still will the seeds, tho' chos'n with toilsome pains,
> Degenerate, if man's industrious hand
> Cull not each year the largest and the best.
> 'Tis thus, by destiny, all things decay
> And retrograde, with motion unperceived."
> *Kennedy's Virgil's Georg.*

"Take care to have your corn weeded twice with the hoe, and also by hand.—"(Cato).

"On large estates fields are alternately allowed to lie fallow, in order to save manure."—(Pliny). "Where want of space forbids this, green crops are grown alternately with cereals, and the loss of productive energy is restored by manuring."—(Cato, Columella). "Some agriculturists grow cereals on their fields two years in succession; proprietors, however, forbid this to their tenants."—(Festus). "The land must rest every second year, or be sown with lighter kinds of seeds, which prove less exhausting to the soil."—(Varro).

"Of the leguminous plants, lupines first deserve our attention, because they require the least labour, are cheapest, and of all seeds are the most profitable for the land; they give the best manure for impoverished fields, and will grow on a sterile soil.

"Some of the leguminous plants *manure* the soil according to *Saserna*, and make it fruitful, whilst others *exhaust* it, and make it *barren*. Lupines, beans, peas, lentils, vetches are reported to manure the land. Of lupines and vetches I believe this to be truly the case, provided they be cut down green, and ploughed in before they are dry."—(Columella). "Linseed, poppy, and oats *exhaust* the soil."—(Virgil). "For fields that have suffered from the cultivation of these plants, manuring is the only efficacious means by which the lost productive energy of the earth is restored."—(Columella). "There are three kinds of manure: the best is the excrement of birds; then comes that of man; and lastly, that of cattle. The last also varies in quality. Asses' dung is the best; then follow sheep's dung, and that of goats, horses, and cattle; the least efficacious of all is the dung of swine. Where an estate consists altogether of corn-fields, there is no need to put on every kind of manure separately; but where there are plantations of trees, arable land, and pasturage, every kind of manure should be applied separately."—(Columella). "Pigeons' dung (guano) should be spread on meadows and gardens, or over the seeds."—(Cato, Varro, Cassius). "Horse-dung is about the best suited for meadow land, and so in general is that of beasts of burthen fed on barley; for manure produced from this cereal makes the grass grow luxuriantly."—(Varro).

"Ash also is used with advantage on fields; and on the other side of the Po," says Pliny, "the use of ash is viewed so favourably by farmers, that they actually prefer it to the manure furnished by their cattle. Should there be no kind of manure at hand, the example of my paternal uncle, M. Columella, may be followed with advantage; he would not manure his vineyard, as he was of opinion that this tended to impair the fine flavour of the wine; but he applied a layer of artificial mould, or earth brought from the woods, and made sure of obtaining by this means a more abundant vintage. Where no kind of manure is to be had, I think the cultivation of lupines will be found the readiest and best substitute. If they are sown about the middle of September in a poor soil, and then ploughed in, they will answer as well as the best manure."—(Columella).

"Agriculturists ought to know that a field will indeed lose its productive power when left altogether unmanured; but that, on the other hand, over-manuring is also very prejudicial. Let farmers, therefore, manure their fields often, rather than over much at a time."—(Columella).

"I have here one more remark to add, namely; that manure is best suited for the field when it is a year old. In summer it ought to be turned up and always kept moist, in order that the seeds of noxious weeds in it be rotted, and be not again returned to the land."—(Col.)

"The best fodder plants are lucerne, fenugreek (*Fœnum græcum*), and vetches. Lucerne may be placed in the foremost rank of such plants; for when it is once sown, it lasts ten years, fattens lean cattle, and has a salutary action on sick cattle. It must be carefully weeded at first, lest the weeds choke the tender lucerne."—(Columella.)

"A field is not sown entirely for the crop which is to be obtained the same year, but partly for the effect to be produced in the following; because there are many plants which, when cut down and left on the land, improve the soil. Thus, lupines, for instance, are ploughed into a poor soil, in lieu of manure."—(Varro.) "Mow your hay at the proper season, and take care not to be too late with it; you must cut it before the seed ripens, and store the best hay separately."—(Cato.) "Mossy meadows may be improved by a fresh sowing, or by manuring; but neither of these operations will answer so well as frequent strewing with ash, which destroys the moss."—(Columella.)

All these rules had, as history tells us, only a temporary effect; they hastened the decay of Roman agriculture; and the small farmer ultimately found that he had exhausted all his expedients to keep his fields fruitful, and reap remunerative crops from them. Even in Columella's time, the produce of the land was only fourfold. The fields fell into the hands of the large landed proprietors, who, by employing a multitude of slaves, were for a time enabled to obtain "the largest crops at the least expenditure of manure." Even by these means the land was in the end not able to bear the heavy taxation; and, as the history of the first three centuries of our era informs us, there ensued a condition of the population, the most calamitous and frightful into which a nation can fall. It is true that many causes co-operated in producing this result, but assuredly one of these was the exhaustion of the soil by the spoliation system of agriculture then pursued.

LETTER XIII.

The true object to be kept in view in establishing Scientific Principles—In scientific agriculture, "Manure," like the term "Phlogiston," has no longer a meaning—The cultivation of Green Crops for the purpose of keeping a stock of Cattle for manure is not necessary in the cultivation of land—The distinction between the Necessity and the Utility of keeping cattle—No necessary connection exists between the production of Corn, and that of Flesh and Cheese—The fundamental principles of German Agriculture quite unknown in China—Chinese Agriculture—The manures employed by them—Great value set by Chinese on human excrements; their mode of collecting and using them—Chinese compost—Their mode of sowing and transplanting wheat—Plants cultivated as green manure for rice fields—The lesson taught by the Chinese system of agriculture.

I WILL show the teachers of agriculture another people, who, without the aid of science, of which they know nothing, have found the philosopher's stone, which these very teachers, in their blindness, vainly seek. I will point out to them a land, the fertility of which has for three thousand years never decreased, but, on the contrary, has been ever on the increase; and where more men are crowded together on a square mile than are to be found on the same space in Holland or England.

According to the testimony of all reports of our own and former times, made by Davis, Hedde, Fortune, and others, and which have been fully borne out by the special inquiries into the state of Chinese husbandry, instituted on the spot at my request, by the direction of the late Sir Robert Peel, it appears that in China, nothing is known of *meadow culture*, or of *fodder plants*, which are grown for the sake of cattle. *Farm-yard manure* is equally unknown; every field yields *produce twice a year*, and is never allowed to lie *fallow*.

Wheat often produces one hundred and twenty fold and upwards (Eckeberg); and a fifteen-fold crop is considered an average yield (Davis). All those means which the German teacher of agriculture regards as *indispensable* for increasing the produce of our fields, and instructs his followers to employ, are not only *entirely* dispensed with by the Chinese farmer, but he actually obtains, without their co-operation, crops which exceed more than two-fold those of the German high farmers.

I readily admit that the Chinese are differently circumstanced from what we are in Europe. Most of them are Buddhists, and eat no beef; we eat more flesh, and must consequently grow fodder for the production of that article of our diet. But that is not the question before us, but one which concerns those principles that are to guide the practice of husbandry. Our teachers of modern agriculture do not tell us to grow fodder that flesh may be produced; but that we ought to do so for the purpose of forming manure; which clearly shows that they have no just conception of the true nature and aim of agriculture, and that they are altogether ignorant of scientific principles in the matter.

In laying down a scientific principle, the first point for consideration is not whether the application of it will turn out profitable or not; but whether it is *true;* for if it is a true principle, it *must* prove advantageous.

In scientific agriculture "manure" finds no longer a place; for the notions that were formerly attached to the term are completely obsolete; just as is the case with the word *Phlogiston,* which, up to the end of last century, was used to explain chemical phenomena.

So long as the nature of Phlogiston was unknown, that word served as a collective term to connect together, in an intelligible form, a number of *unknown* operating causes; but when it had once been settled what "Phlogiston" really meant and represented, the term had to give way to more correct ideas; and interpretations of phenomena became what they had never been before, viz. real and trustworthy. Wood does not, on that account, burn differently now-a-days from what it formerly did; the air played the same part in its combustion then as now; and water still possesses the same property of making bodies wet; but what immense progress has been made by mankind, as the result of substituting for the word "Phlogiston," the proper conceptions of the nature of air, of oxygen, and of the process of combustion!

A similar progress, but much more important, and infinitely more beneficial to man, will spring from a correct apprehension of the process of nutrition in plants and animals. Absurd as would now be the attempt of a teacher of Chemistry to account for any chemical process by having recourse to phlogiston, it is no less inadmissible in a teacher of scientific agriculture to explain a given fact by attributing it to "manure;" for, in the place of the obsolete notion of "manure," *which has no longer any meaning*, we have now for every plant certain positively known *elements of food*, to the united action of which we have to look for an explanation of the fact or phenomenon in question.

The doctrine which inculcates as necessary for the cultivation of the land, the production of manure by green crops, and along with this the maintenance of a stock of cattle, is erroneous.

It is necessary here to distinguish between *necessity* and *utility*. A stock of cattle may prove very useful to the farmer, and yield him a remunerative return in butter, cheese, and meat; but this is quite a distinct affair from the tillage of his fields, and he ought to know, and must be taught, that there is absolutely no compulsion upon him to keep a stock of cattle.

The keeping of cattle is necessary for the production of manure; but the production of manure is by no means necessary for the fertilisation of corn fields. In the system of the rotation of crops, *all that is required is* that green crops should be grown, and that their constituent parts be incorporated with the arable surface soil of the field; and it is quite immaterial for the cereals whether the green crops be previously eaten by the cattle and converted into manure or not.

If lupines, vetches, clover, turnips, &c., are cut up and ploughed in, in the green state, their action is far more powerful.

There is no natural connection of mutual dependence between the production of corn and that of flesh and cheese; on the contrary, they interfere with each other, and must in science be considered as perfectly distinct and separate things; for the production and sale of flesh is carried on at the expense of grain, and *vice versâ*. We cannot do without meat, milk, or cheese; and if the production of these articles be left entirely to the grazier, who, on his part, ought to meddle as little as possible with the growing of grain, both he and the farmer, as well as the consumer, would profit by it. In England this separation of the two pursuits is gradually gaining ground; and when, as is to be hoped, our German farmer shall have succeeded, in the course of time, in mastering the multiplication table, we may expect that the same separation will take place in Germany. Chemical manufactories are not established anywhere and everywhere, but only in localities offering certain natural advantages; and Agriculture, after all, is simply an industrial pursuit, like any other.

In China they know nothing of the fundamental principles upon which German agriculture is based. Except green manuring, they neither know nor esteem the application of any kind of manure beyond the excrements of man. The other matters occasionally employed by them to increase their crops, are in quantity and effect utterly insignificant, when compared with the use of human excrements.

It is quite impossible for us in Europe to form an adequate conception of the great care which is bestowed in China upon the collection of human excrements. In the eyes of the Chinese, these constitute the true sustenance of the soil (so Davis, Fortune, Hedde, and others tell us), and it is principally to this most energetic agent that they ascribe the activity and fertility of the earth.

The Chinese, whose house is still, what it most probably has ever been, a tent, only that it is built of stone and wood, knows nothing of privies as we have them in our country; but, in their stead, there are found in the principal and most comfortable part of his dwelling, earthenware tubs, or cisterns most carefully constructed of stone and lime; and the notion of utility so completely prevails over the sense of smell, that, as Fortune tells us ("The Tea Districts of China and India," vol. i., p. 221), "what in every civilised town of Europe would be regarded as a most intolerable nuisance, is there looked upon by all classes, rich and poor, with the utmost complacency, and," he continues, "nothing would cause greater surprise to a Chinese than to complain of the stench arising from these receptacles." The Chinese do not disinfect this manure; but they are perfectly aware that it loses part of its fertilising power by the action of the air;

and they, therefore, take great care to guard against evaporation.

Except the trade in grain, and in articles of food, generally, there is none so extensively carried on in China as that in human excrements. Long clumsy boats, which traverse the street canals, collect these matters every day, and distribute them over the country. Every Coolie who has brought his produce to market in the morning, carries home at night two pails full of this manure on a bamboo pole.

The estimation in which it is held is so great, that everybody knows the amount of excrements voided per man in a day, month, or year; and a Chinese would regard as a gross breach of manners the departure from his house of a guest who neglects to let him have that advantage to which he deems himself justly entitled in return for his hospitality. The value of the excrements of five people is estimated at two Teu per day, which make 2000 Cash * per annum, or about twenty hectolitres (440 galls.), at a price of seven florins.

In the vicinity of large towns, these excrements are converted into poudrette, which is then sent to the most distant places, in the shape of square cakes, like bricks. For use, these cakes are soaked in water, and applied in the fluid form. With the exception of his rice fields, the Chinese does not manure the field, but the plant.

* 100 Cash are equal to about 4½*d.* (Fortune).

Every substance derived from plants and animals is carefully collected by the Chinese, and converted into manure. Oil cakes, horn, and bones, are highly valued, and so is soot, and more especially ash. To give some notion of the value set by them upon animal offal, it will be sufficient to mention that the barbers most carefully collect, and sell as an article of trade, the somewhat considerable amount of hair of the beards and heads of the hundreds of millions of customers whom they daily shave. The Chinese know the action of gypsum and lime; and it often happens that they renew the plastering of the kitchens, for the purpose of making use of the old matter for manure.—(Davis.)

No Chinese farmer ever sows a seed of corn before it has been soaked in liquid manure diluted with water, and has begun to germinate; and experience has taught him (so he asserts), that this operation not only tends to promote the growth and development of the plant, but also to protect the seed from the insects hidden in the ground.—(Davis.)

During the summer months, all kinds of vegetable refuse are mixed with turf, straw, grass, peat, weeds, and earth, collected into heaps, and when quite dry, set on fire; after several days of slow combustion, the entire mass is converted into a kind of black earth. This compost is only employed for the manuring of seeds. When seed time arrives, one man makes holes in the ground; another follows with the seed, which he places in the holes; and a third adds this black earth.

The young seed planted in this manner grows with such extraordinary vigour, that it is thereby enabled to push its rootlets through the hard solid soil, and to collect its mineral constituents.—(Fortune.)

"The Chinese farmer sows his wheat, after the grains have been soaked in liquid manure, quite close in seed-beds, and afterwards transplants it. Occasionally, also, the soaked grains are immediately sown in the field properly prepared for their reception, at an interval of four inches from each other. The time of transplanting is towards the month of December. In March the seed sends up from seven to nine stalks with ears, but the straw is shorter than with us. I have been told that wheat yields 120 fold and more, which amply repays the care and labour bestowed upon it."—(Eckeberg, Report to the Academy of Sciences at Stockholm, 1765.)*

* The *Dresden Journal*, of 16th September, 1856, contains the following statement:—"As we are informed from Eibenstock, forest-inspector Thiersch, of that place, has for several years past made very successful experiments in transplanting winter corn in the autumn. He transplanted the young plants intended for the purpose in the middle of the month of October, one peck of seed-corn to one hundred square rods of ground, which produced an uncommonly rich crop. There were roots from which sprung as many as fifty-one stalks with ears, and the latter contained as many as one hundred grains."

I have applied to Mr. F. J. Thiersch for more precise details of his experiments; and from his statement as to the cost of the operation and the return made, there appears to be no doubt that the Chinese mode of husbandry might also be resorted to with advantage in Europe, in localities where the land is rich and labour abundant. One of my friends, who visited M. Thiersch's experimental field, told me that he had counted twenty-one stalks with full ears on a plant pulled up at hazard (not picked out). For poor fields this method of cultivation is entirely unsuited.

In Chusan, and the entire rice districts of Chekiang and Keangsoo, two plants are exclusively cultivated for the purpose of serving as green manure for the rice fields; the one is a species of Coronilla, clover is the other. Broad furrows, similar to those intended for celery, are made, and the seeds are planted on the ridges in patches, at a distance of five inches from each other. In the course of a few days germination begins, and long before the winter is gone, the entire field is covered with a luxuriant vegetation. In April the plants are ploughed in; and decomposition soon begins, attended with a most disagreeable odour. This method is adopted in all places where rice is grown.—(Fortune, vol. i., p. 238).

These extracts, which, from want of space, cannot be further extended, will probably suffice to convince the German agriculturist, that his practice, when compared with that of the oldest agricultural nation in the world, stands somewhat in the position of the acts of a child to those of a full grown and experienced man. The Chinese system of husbandry is the more remarkable, and if we take into account what they have achieved in other mechanical and chemical pursuits, more incomprehensible, as they owe everything to the purest empiricism. For the Chinese system of instruction has, for thousands of years, so thoroughly excluded every inquiry after an ultimate cause of things, which might possibly have led to the discovery of scientific principles, or to the establishment of a science, that the capability of making further progress, except by imitation, would seem to be destroyed to the very root in that people. The study of the physical laws, which has led European nations to the invention of the steam-engine, and of the electric-telegraph, and has enabled man to control and turn to his account the forces of nature in numberless other instances, is a matter of absolute impossibility to the Chinese scholar. It is the express command of their first and most ancient teacher of religion, Confucius, that the student shall never allow any thought to rise in his mind but such as he finds written in his books.

It is quite true that what suits one people may not on that account suit all countries and all nations; but one great and incontrovertible truth may, at all events, be learned from Chinese agriculture, viz., that the fields of the Chinese cultivator have preserved their fertility unimpaired, and in continued vigour ever since the days of Abraham, and of the building of the first Pyramid in Egypt.* This result we also learn has been attained solely and simply by the restitution to the soil of the mineral constituents removed in the produce; or what amounts to the same thing, that this has been effected by the aid of a manure, of which the greater portion is lost to the land in the European system of cultivation.

* Vessels of Chinese porcelain are found in the Pyramids, of the same shape, and with the same characters of writing on them, as are made in China at the present day.

LETTER XIV.

The law of Compensation is of universal application—Elementary information on Chemical subjects connected with Agriculture easily imparted—Importance of instructing youth at school in these fundamental truths—Theoretical instructions should always precede Practical—The proper mode of instructing agriculturists in the Theory and Practice of Agriculture—The present constitution of Agricultural institutions very defective—The false position of Science in practical agriculture is the result of the teachings of these Schools—The demands made by Science on agriculturists are simple, and a knowledge of them cannot prove injurious—Science demands that agriculturists should test the Truths she advances—The truths in these Letters expressed by a Formula—The value of Guano first discovered by Science—The establishment of Reservoirs for animal excreta strongly recommended—Reliance to be placed upon such Excreta rather than on Guano—Chemistry can only help agriculturists after they have exhausted all the means at their disposal—Notes on supply of guano and on the agriculture of Tuscany.

The European husbandman has, for centuries past, been in the habit of taking away the produce of his fields, without making compensation for the mineral matters removed, and his fields have accordingly been continually diminishing in fertility.

The Chinese husbandman has, for thousands of years past, made it a practice to restore to his fields the mineral constituents removed from them in the produce, and the fertility of his land has accordingly kept pace with the increase of the population.

The law of compensation, which makes the recurrence or permanency of effects dependent upon the recurrence or permanency of the conditions which produce them, is the most universal of the laws of nature; it governs all natural phenomena in their various phases, all organic processes, all the productions of man's industry. That the agriculturist alone should ignore this law, nay, that his teachers and guides should actually deny its operation, shows clearly the condition of the schools in which the sons of our farmers are taught.

What Chemistry teaches about air, water, the process of combustion, arable soil, the ash of plants, manure and its constituents, is so easy of comprehension, that every well-informed teacher may, in a dozen lessons, and with the simplest means of instruction, impart to the commonest peasant boy an accurate knowledge of these things; particularly if the teacher strictly confine himself to his subject. The lectures occasionally delivered on matters of this nature at the Royal Institution of London, by Professor Faraday, before an audience of children, may be adduced in proof that it is quite practicable to do so.

By command of King Maximilian, a movement in this direction has of late been made in Bavaria. Five years ago, all the teachers of the schools for training schoolmasters were, for this purpose, specially instructed and exercised in Munich.

The diffusion of this elementary knowledge among the peasantry through the agency of the schoolmaster, will be an immense step in advance, and will prove the very best thing that the state can do in the interest of agriculture.

The boy who has been taught at school, even though superficially, the conditions on which the fertility of the field depends, and who has been told by his teacher that he who uselessly wastes these conditions is guilty of an offence against the poor, against himself, and against society, will certainly, when he grows up to man's estate, construct receptacles for human and animal excrements, such as no police regulations could ever compel him to provide.

A superficial examination of the system prevailing in the higher agricultural institutions, is sufficient to convince us that, such as they are at present, they are totally unsuited for the requirements of our day.

The combination of the ordinary arrangements of a school, with instructions in the practical work of agriculture, does away with the benefits which might be derived from such institutions, which are neither one thing nor another; they are neither educational institutions nor good practical workshops; they possess some of the features of both, but none of the good points of either.

The technical part of an industrial pursuit can be learned; principles alone can be taught. To learn the *trade* of husbandry, the agriculturist must serve an apprenticeship to it; to inform his mind in the *principles* of the *science*, he must frequent a school specially devoted to this object.

It is impossible to combine the two; the only practicable way is to take them up successively. I formerly conducted at Giessen a school for practical chemistry, analysis, and other branches connected therewith, and thirty years' experience has taught me that nothing is to be gained by the combination of theoretical with practical instruction. A student of chemistry who attends the lecture-hall and the laboratory concurrently, positively defeats thereby the object of his stay at the school, and misses the aim of his studies. It is only after having gone through a complete course of theoretical instruction in the lecture-hall that the student can with advantage enter upon the practical part of chemistry; he must bring with him into the laboratory a thorough knowledge of the principles of the science, or he cannot possibly understand the practical operations. If he is ignorant of these principles, he has no business in the laboratory.

In all industrial pursuits connected with the natural sciences, in fact, in all pursuits not simply dependent on manual dexterity, the development of the intellectual faculties, by what may be termed "school learning," constitutes the basis and chief condition of progress and of every improvement. A young man, with a mind well-stored with solid scientific acquirements, will, without difficulty or effort, master the technical part of an industrial pursuit; whereas, in general, an individual who may be thoroughly master of the technical part, is altogether incapable of seizing upon any new fact that has not previously presented itself to him, or of comprehending a scientific principle and its application.

I have often found that students coming from good colleges will speedily leave the pupils of industrial and polytechnic schools far behind them even *in the natural sciences,* though the latter, when compared with the former, were at first giants in *knowledge.*

I am far from wishing to question in any way the very great utility of industrial and technical schools. I consider them just as indispensable as higher schools; for the same road is not suited to all men, and every one does not possess an aptitude for the study of languages. The minds of youth may be compared to a variety of ores, requiring different furnaces for the smelting and extraction of the metal, and the removal of the slags. But talent is like gold; wherever it occurs in nature it is found in its pure state, never as an ore, and every furnace is equally suited to it.

In our agricultural academies the training of the pupils in the mechanical and technical branches is continually interfering with their proper instruction in principles and theories in the school. Whenever a new sowing machine, or a plough, or some other agricultural implement is to be tried, the lecture-halls of Chemistry, Physics, &c., are deserted. The greater portion of their teachers of Mathematics and the Natural Sciences have received a university education, and are, as may be expected, able scientific men; but their teachings are held of secondary importance to the practical work of husbandry; they become speedily discouraged; and, under such circumstances, a solid course of instruction in the natural sciences is out of the question. I never yet met with one pupil trained at one of these institutions, who had a correct conception of the theory of dew, or who was able to distinguish the seeds of the meadow grasses, or the grasses themselves.

The learning of a technical pursuit is a different thing from the acquirement of an art which demands practice. The pupil of an academy of fine arts may see from day to day what progress he has been making; and this gives him the necessary encouragement, which again tends to stimulate his ardour, and makes him persevere in his efforts. But the pupil at an agricultural academy has no standard by which to measure the progress he has been making in technical knowledge; the incentive to exertion is wanting, and all emulation *ceases.*

The young agriculturist who wishes to acquire a competent knowledge, both theoretical and practical, of his pursuit, ought to visit, in the first place, a university to obtain the necessary knowledge of the natural sciences, and afterwards an agricultural institute, where the principles of agriculture, and, at the same time, its practical operations, are taught on a large scale.

Now, if we reflect that the majority of our agricultural academies have, for a generation past, been conducted in a measure by men who have no knowledge whatever of Chemistry, Physics, Botany, Geognosy, &c., the conviction forces itself upon the mind, that they have been much more schools of idleness, and of opposition to all progress, than institutions for advancement.

The conflict at present raging about the principles of science and their application to practical husbandry, is the work of these schools; and no one need wonder if the practical man should hold science in little respect, nay, if he should regard it with positive contempt. For, whence can this estimation and regard for science proceed, except from a knowledge of its principles?

I am ready and willing to retract every word I have uttered against these institutions, if any one will solve, in some other way, the enigma which the antagonism between the precepts of science and the practical lessons of agriculture presents. The former do not simply embrace the principles at which a single individual has arrived; but they comprehend the general principles of all science. All chemists and physicists, all students of nature and mathematicians, entertain them, because they are simply expressions of that method to which they owe all their success.

All practical men are agreed on this *one* point, that they ought not to alter their practice on account of a doctrine however probable it may appear; they demand to be first convinced of its truth, and then, as a matter of course, all opposition on their part will cease. This condition would be reasonable enough, were there anything in this doctrine which might possibly prove injurious to their interests; but their opposition is not directed against the doctrine, but against common sense, and no science in the world can overcome opposition of such a nature.

The scientific principles which chemistry wishes to introduce into agriculture are so very simple, and the demands made upon the practical husbandman are so much to his own advantage, that, to an unprejudiced person, his opposition is incomprehensible.

Science has taken upon herself to accomplish what was beyond the power of practice, from its very nature, to do. She has thoroughly examined the soil, the air, the excrements of man and of animals, the roots and tubers of plants, their leaves, stalks, seeds, and fruits, the blood and flesh of animals; she has, in short, investigated everything of a combustible and incombustible nature contained in organic bodies, and which is of importance in their production. The results of her researches and analyses she has laid before the practical agriculturist, and has shown him that *plants*, *manures*, and the *soil*, have certain constituent elements in common. From the constant presence of these constituent elements in plants, she has inferred that they are *indispensable* to the formation of the *plant* and its parts—an inference which naturally leads to the conclusion that they are equally *necessary* in the *soil* in which the plants are to grow, as well as in the *manure* which is intended to aid their growth. Science has also demonstrated, still with the balance in her hands, that even a soil regarded as abounding in these constituent elements contains in reality only a comparatively very small proportion of them.

Science demands from the practical agriculturist no more than that he should acquire the very trifling amount of chemical information requisite to enable him to understand the language of chemistry, and to test the correctness of these facts. It would be absurd in the extreme to fancy that this could in any way tend to interfere injuriously with the practical operations of husbandry. She asks the farmer to test the correctness of these facts in his own way; to prove by actual experiment, whether a field which does not possess these constituent elements, is nevertheless a fruitful soil for the production of cultivated plants; and if not, whether it may be made fruitful by a proper supply of these matters. She asks him further to try if a field abounding in these elements is rendered barren by their removal from it. Surely a trial of this kind cannot be said to be of a nature likely to interfere injuriously with the practical operations of husbandry.

When agriculturists have in this way acquired the conviction that the facts and inferences of chemistry agree with the facts and results of the agricultural test applied, everything has then been done that can be done by chemistry for agriculture. The instructions given beyond this no longer pertain exclusively to the domain of chemistry, but are common to all sciences.

When, therefore, the agriculturist has, in the manner just described, ascertained that the facts and inferences advanced by chemistry are fully borne out by the results of agricultural experience, it can surely only be to his own advantage to shape his practice by her lessons, and to make the necessary changes in those portions of his operations which he finds have been founded in error. It is not chemistry alone, but common sense, and everything besides connected with these facts, which require him to do this. Common sense tells him that he ought to provide for his fields a proper supply of these constituent elements, and restore them where they have been taken away, if he wishes to make a barren soil produce fruit, or increase the fertility of a fruitful field, or keep a *very* fertile field constantly at the same *high degree* of productiveness; it tells him that the art of the agriculturist cannot simply consist in lowering the *high* productiveness of a field to the level of *ordinary* fertility, and in turning a fruitful into a *sterile* field.

It is held as a fundamental principle in science, that every opinion, before it is admitted as true and taught to others, should first be established by proper proofs, which must not in any way run counter to undoubted truths, such as, for instance, that twice two are four, and not five. Inferences and conclusions which are opposed to such truths are rejected by science, and it cannot surely be considered an unreasonable request, to ask agriculturists to adopt the same principle as a guide in drawing their conclusions. Now, it is actually upon these points that the conflict turns; for the opposition is in reality directed, not so much against the facts and teachings of chemistry, as against the deductions drawn from them by common sense.

The exposition of the scientific principles of agriculture is not a thing of yesterday, but dates so long ago as seventeen years; and the system of husbandry as taught in our agricultural institutions (see Letter I.), could certainly not have so long withstood the power of truth and common sense, had it not been separated from them as if by a wall, and defended from their attacks.

The chemical truths in these Letters may be expressed by a simple formula, which, though bearing a somewhat mathematical appearance, is yet plainly intelligible to every one:

$$P = F - R.$$

The P in this formula stands for Produce (Corn, Potatoes, Turnips, &c.); the F stands for Food (Phosphoric acid, Potash, Lime, Ammonia, &c.); the R stands for Resistance.

Expressed in words the formula stands thus:

The amount of produce yielded by a field corresponds with, or is proportionate to the quantity of food in the soil (to the conditions for the production of the crop), *minus* the sum of the resisting forces which hinder the production of the crop from the elements of food present. Let the letter F stand for six slices of an apple, and the letter R represent three fingers keeping a firm hold on two out of the six slices, there will remain only four slices free, which may be eaten by another person.

The entire contents of these Letters are simply a development of this formula. Everything that is said in them about amount and increase of produce, fertility, cultivation of the soil, manure, &c., is comprised in it. It is evident that if the formula be true, its application will embrace millions of receipts for the improvement of millions of fields, and for the continued production of the largest crops; and that the future prospects of our fields, and wealth and income of all agriculturists, will be dependent upon its strict and rational application. No one can then deny, that the development of this formula is of some importance to agriculturists, and its discussion of some value to them.

Whatever progress has been made by practical agriculture for some thousands of years past in the knowledge of manures, is clearly referable to those true principles which constitute the basis and conditions for correct conclusions.

Guided by a careful study of the elements of the food of plants, science, in the year 1840, pointed out to the agriculturist guano as one of the most infallible means of raising the produce of corn and flesh, and most urgently recommended its application. Before 1840, guano had never been used as manure on a European field. When the first vessel loaded with guano arrived at Liverpool, numerous experiments were made with the new manure, which proved failures; and agriculturists were not agreed about its utility until they had practically tested its use. Since that time many hundreds of ships have passed to and fro, and have brought to the European Continent guano to the value of above 300,000,000 florins (£25,000,000); and within the same period there has been produced a surplus of more than 400,000,000 cwt. of corn, or of its equivalent in flesh. It is true, guano would have found its way to Europe even without the recommendation of science; for a kind Providence makes the apple ripen in proper season, and if it drops from the tree and rots, the fault lies with man, or with the soil, if the seeds do not germinate. But guano would probably not have made its way so speedily. In the late seasons of sterility through which we have passed, it has been the means of alleviating the wants of many millions of men.

The man of theory who predicted the effects of guano had not seen the favourable results of its application, which our "Nitrogen champions" had subsequently occasion to observe in England; but the predictions of its utility had been simply based on the results of its chemical analysis, and was only a corollary deduced from the principle, that it *is indispensable to restore to* *the field exhausted by the growth of corn, the mineral elements taken away in the crops.*

Not pseudo-chemistry, but science, placed in the hands of the agriculturist the means of making phosphate of lime more readily available for the nutrition of plants, by treatment with sulphuric acid; and the results of the practice in England for the last ten years have shown, that by the use of this means the amount of provender for cattle has been increased to the same extent as if the area of every field for green crops had been doubled. There have been produced since then, on the same area, many million cwt. more flesh than formerly, or its equivalent in corn.

And the man of theory who advised the use of this means had not seen its effects, as our agricultural chemists in England have seen them; but he had simply inferred them from the principle, that *the action of a manuring agent in a given time must increase in proportion as its surface increases.*

Whatever practical agriculturists and agricultural societies may do, whatever they may resolve at their annual meetings, every penny spent will be thrown away, and every year of experimenting will be in vain, so long as these practical men will not submit to the teachings of true experience, to the rules of logic or of common sense: from the instant they shall so submit, science will be theirs.

There exists a receipt for insuring the fertility of our fields and the permanence of their crops, and which, if properly and consistently applied, will prove more remunerative than all the expedients that have ever before been resorted to by agriculturists. It consists in the following rule:

Every farmer who takes a sack of corn, or a cwt. of rape, turnips, potatoes, &c., to the town, ought, like the Chinese coolie, to carry back with him from the town an equal (or, if possible, a larger) quantity of the mineral constituents of the produce sold, and restore them to the field from which they have been taken. He should not despise the peel of a potato, nor a straw, but always bear in mind that that peel may be wanting to form one of his potatoes, that straw to form one of his ears of corn. The cost of carrying these matters to his fields is trifling, and the investment is as safe as a savings-bank, and highly productive withal. The fertile area of his field will, in the course of ten years, be as it were doubled; he will produce more corn, more flesh, and more cheese, without having, on that account, to bestow greater labour and time upon the cultivation of his land; he will be less anxious about his fields, and need no longer keep his mind constantly on the stretch for some new, unknown, and imaginary expedient to preserve their fertility in some other way.

All the proprietors of the soil in every great country ought to form a society for the establishment of reservoirs where the excreta of men and animals might be collected, and converted into a portable form. Bones, soot, ashes, lixiviated and unlixiviated, the blood of animals, and offal and refuse of all kinds, ought to be collected together in these establishments, and prepared for transport by the society's own officials.

To render the execution of a plan of this kind possible, government and the police authorities should take measures to insure the proper construction of latrines and sewers in towns, to guard against the waste of the night-soil, &c.* This must of course be a preliminary arrangement; but, when once made, an annual subscription of half-a-florin from every farmer, every peasant in the land, will suffice to call into existence establishments of this kind in every town; and there can be no doubt that these establishments will speedily become self-supporting, if every agriculturist will only make up his mind to act strictly upon the advice here given.

Agriculturists must not rely upon guano; its price at the present time, as compared with an earlier period, is already doubled; and no sensible man would entertain the idea of making the production of an entire country dependent on the supply of a foreign manure.†

* Judicious arrangements have already been adopted last year in Munich, by the Minister of the Interior, with a view to the improvement of the sanitary condition of the city. The success of these measures will materially depend upon the manner in which the proprietors of the houses appreciate and aid the wise intentions of government.

† It is almost to be feared that guano will play a momentous part in history. When it is considered that one cwt. of that manuring agent contains the effective mineral constituents of between 25 cwt. and 30 cwt. of wheat, or of an equivalent amount of some other produce, and that, when used as manure, it produces, in a succession of crops, a corresponding quantity of elements of food, some conception may be formed of the immense value which the guano beds of America possess, with reference to the production

Agriculturists must in the first place learn to turn to the best account all the means and resources at their command; when they have done this, but not till then, will chemistry be able to do them good and useful service. But so long as they expect this science to present them with potent charms for fertility, there is no help for them. They must bear in mind, that wherever success does not attend a good cause, the fault lies in want of energy in using the proper means; for these are always to be found.*

of corn in Europe. From the enormous increase of the population of London, and other large cities of Great Britain, the loss which the English fields sustain annually in the main conditions of their fertility, is every year becoming more and more considerable; and it would appear that the obstacles which oppose the collection of the human and animal excrements are altogether insurmountable, at least as regards London. It is evident, therefore, that England, in order to remain permanently a corn-growing country, requires a free and plentiful supply of guano (even now Great Britain consumes nearly nine-tenths of all the guano brought to Europe). Fifteen years ago the American agriculturists looked down upon guano with a species of contempt; but things have greatly altered since then; and it is said that last year about eight million cwt. of that manuring agent were imported into the United States. In the actual position of English Agriculture, America, by her guano-beds, rules the prices of all the corn-markets of Europe, and more especially in England; and should circumstances ever arise to prevent the importation of guano into England, a state of things would ensue in that country of which the consequences might be incalculable. Bloody wars have sometimes sprung from causes of much less importance.

* If we ask the opinions of different persons on the question of "sewage," we receive contradictory answers. All manufacturers of super-phosphate of lime are quite agreed on the point, that only the fluid portions of sewage, or the matters dissolved in sewage water, are valuable in agriculture. They do not, in giving this opinion, deny the good effect of the solid matters, but only mean to say that they are not worth the trouble of being collected for manure, because they are ready to deliver from their manufactories these matters to agriculturists. The manufacturers of ammonia salts, and the dealers in guano take an entirely opposite view. These hold that only the solid sewage matters are to be looked upon as important. There

can, however, be no doubt that both the fluid and solid matters are valuable for agriculture.

"The use of these fertilising matters is not confined to the estates and farms in the immediate vicinity of the centres of population and consumption. Our peasants go long journeys with their wretched carts to seek substitutes for the deficient quantity of their farm-yard manure. The industrious peasant of Lucca is worthy of ranking with the Chinese coolie. Enjoying the blessings of irrigation within a circle of twenty-eight miles (English), the former, who has never even heard of the name of guano, manages to reap two crops in the year ; and yet never allows his land to lie fallow. He goes, however, with his cart, not only to the neighbouring town of Lucca, but even as far as Pisa and Leghorn, to collect the contents of the sewers, with the aid of which he produces, by indefatigable labour, marvellous crops, and raises food sufficient for the most dense population of the old duchy. The boats of Viarreggio carry from this port the goats' dung of the Maremma, to manure the olive trees of the Apuan coast."

"From the peculiar circumstances in which our Maremmas are placed, they are debarred from the benefit of a like restitution of the conditions of fertility. Cultivation slowly improves, and the amount of produce reaped increases every year ; but the scanty and migratory population of a soil, deserted on account of the miasmatic exhalations, cannot yield an amount of fertilising matter in proportion to the quantity carried off from the land. The gradual introduction of the system of the rotation of crops might slowly lead to the same impoverishment of the soil which has resulted in other places from the 'high system of farming.' The apprehension lest this should in reality be the result of it, has by no means escaped the attention of the proprietors and cultivators of the soil in the Grand Duchy, who are so earnestly endeavouring to make agriculture flourish in these parts. The barrenness and desolation which has so long been the fate of the Maremma may, perhaps, be partly attributable to the spoliation system of farming pursued by the ancient Romans and Etruscans."

"Agriculture in Tuscany, then, is based upon the principle of restoring to the soil those elements which science points out to be the most efficacious for the growth of plants ; and in this respect it is far ahead of the system pursued in other countries," &c.—(*Sei nuove lettere chimiche sull' agricultura di Giusto Liebig, compendiate et annotate de Gustavo Dalgas, Dr. Philosoph. Firenze, Felice Paggi*, 1858, p. 93.)

APPENDIX.

TO LETTER VI.

In the cultivation of grass for a season merely, or in the planting of a particular kind of grass or of several sorts combined, the nature of such grass or grasses is essentially a matter for consideration, but not so in the case of the sward. Just as the beech tree when standing alone covers a broad space, and nearly sweeps the earth with its richly-leaved boughs, while a number of the same trees, standing closely together, tower upwards like columns, and merely clothe themselves with branches and leaves at the very summit, so in the sward of the natural meadow, plant closely clings to plant, altering its very structure in yielding to the law of necessity.

Those kinds of grasses which do this in a less degree, such as meadow soft-grass (*Holcus lanatus, L.*), are on this account less suited for meadow plants, whilst others, though coarse-tufted, such as cock's foot-grass (*Dactylis glomerata, L.*), and even turfy hair-grass (*Aira caespitosa, L.*), form large separate tufts only with an inferior sward.

In the spring of 1857, I examined a patch of quite new grown turf, which was exceedingly fine and close, taken from the ground facing a ditch used for the draining of a large meadow; I found on an area of 11·85 square in. Hess., 265 grasses. On an older piece of turf taken from the irrigated meadow having an area of 14·4 square in., I found 210 grasses and 12 other plants; and on another patch of an area of 13·2 square in., 150 grasses and 25 other plants.

These high figures sufficed to confirm me in my original supposition, that only a small portion of the store of plants is completely developed in one year, and that a change of plants takes place according to the altered influences of the atmosphere and the soil; a fact which, according to Thaer, has been already noticed by others, and, as it appears, was also observed by Schwerz.

It is well known that many plants, when a condition indispensable to their perfect development ceases to exist, as for instance, where the over-hanging shade of growing timber, or a too great clearance, prevents their growth, will for years retain existence by the extension of their roots, remaining as it were at a lower stage of growth, till there is a return of more favourable circumstances for their development.

Thus we find that cleared ground will frequently become immediately covered with plants, many of which, being perennials, such as the raspberry, could not have sprung from seed. I have proved that this state of things is very general and is not confined to cases alone where the impediments to the growth of the plants are so considerable, but that it applies also more especially to grasses, and is of the highest importance in the cultivation of meadows.

Every one knows that ash draws forth clover plants (which, like the grasses, do not flower the first year); and likewise that after manuring, other kinds of grasses make their appearance on the meadow. I observed on a plot manured with so-called acid-phosphate of lime, the almost exclusive growth of a single kind of grass, French rye-grass (*Arrhenaterum avenaceum*), which came up in thickly serried blades, whilst on the unmanured ground but a few stalks presented themselves.

I have examined the stock of plants on meadows at the time of the development of the culms. I had pieces of turf carefully cut out, measured, and the soil washed away, which left a dense mat of closely interwoven roots. There were found on one square foot, Hess. in :

1. Irrigated meadow near Zerby : Dry patch. Predominant :—*Bromus mollis*, L., *et Arrhenaterum avenaceum* P.B. Size of sod, 22 square inches ; containing 472 plants ; in stalk, 36.

2. Irrigated meadow, same place : wet patch. Predominant : *Glyceria fluitans*. Size of sod, 20 square inches ; containing 1230 plants ; in stalk, 20.

3. Dry unirrigated meadow, near Fehlheim : manured with compost. Predominant:—*Agrostis alba et vulgaris*. Size of sod, 56 square inches ; containing 668 plants, of which there were 601 grasses and 67 other plants ; in stalk, 66.

The other plants consisted of *Lysimachia nummularia*, *Bellis perennis*, *L.*, *Veronica chamædris*, *Ranunculus*, *Rumex*.

4. Irrigated meadow, near Fehlheim, somewhat mossy. Predominant :—*Poa trivialis*, *Festuca pratensis*, *Avena flavescens*, *Festuca rubra*, *Agrostis vulgaris*. Size of sod, 55·25 square inches ; containing 730 plants, of which there were 584 grasses, 182 other plants ; in stalk, 125.

The other plants consisted of *Plantago*, *Daucus*, *Veronica*, *Rumex*, *Ranunculus*, *Chrysanthemum*, *Trifolium repens*, *Lathyrus*.

5. Meadow near Balsbach, in the Hessian Odenwald (counted by Peter Kreuz, of that place). Predominant :—*Agrostis stolonifera* and *Anthoxanthum odoratum*. Size of sod, 1 square foot ; containing 1176 plants, of which there were 1070 grasses, 56 clover, and 80 other plants ; in stalk, 38.

6. Meadow near Balsbach, in the Hessian Odenwald (counted by Peter Kreuz, of that place). Predominant :—*Lolium perenne*, *Festuca pratensis*, *Dactylis glomerata*. Size of sod, 1 square foot ; containing 790 plants, of which there were 710 grasses, 80 other plants (before the second cutting, without stalks).

7. Meadow near Balsbach, in the Hessian Odenwald (counted by Peter Kreuz, of that place). Predominant :—*Festuca rubra*, *Agrostis stolonifera*, *Anthoxanthum odoratum*, *Cynosurus cristatus*. Size of sod, 1 square foot ; containing 920 plants, of which there were 800 grasses, 120 other plants ; in stalk, 14.

In numbers 5, 6, and 7, an entire square foot of sod was examined, which must have been a most arduous and laborious undertaking. The examiner (Mr. Peter Kreuz) says : "We have carefully separated the single plants, and to guard against mistakes, collected them in little heaps of 10, and afterwards in heaps of 100 plants, by putting 10 of the small heaps together."

8. Unirrigated meadow in the parsonage garden of Hohenstein : not irrigated, mossy, with tolerably dry soil (counted by the Rev. Mr. Snell, of that place). Predominant :—*Alopecurus, Dactylis, Arrhenaterum avenaceum.* Size of sod, 1 square foot, Nassau measure ; containing 1040 plants, of which there were 832 grasses, 80 clover, 128 other plants ; in stalk, 208.

The other plants consisted of *Plantago, Leontodon, Veronica, Lysimachia nummularia.*

9. Dry unmanured meadow, near Fehlheim : weedy (counted by the author). Size of sod, 60 square inches ; containing 379 plants to the square foot (Hessian), of which there were 276 grasses, 103 other plants ; in stalk, 0.

The other plants were *Plantago, Prunella vulgaris, Bellis, Ranunculus, Hieracium, Veronica, Carex.*

Sinclair found on one English square foot, equal to about 1½ square foot, Hessian in :

	Plants.	Grasses.	Clover and other plants.
Very rich natural meadow, at Endsleigh . . .	1000	940	60
Rich old meadow, at Croft-church	1090	1032	58
Old meadow at Woburn . .	910	880	30
Old meadow at Woburn, soil moist, surface mossy .	634	510	124
Irrigated meadow . . .	1798	1702	96

If we place the figures given by me by the side of those of Sinclair, properly reduced, we find that they agree as closely as can well be expected :

Hanstein.	Sinclair.
1230	1200
1176	—
920	—
790	726
730	—
668	666
472	606
379	423

This comportment of the grasses is of the highest importance; it explains the fact of the permanent duration of natural meadows, and the certainty of their yield; it is this property that causes "the sward, which in the temperate zone neither heat nor cold can destroy, to be clothed with perpetual verdure."

The large number of plants which are in a low stage of development, await, as if in a slumbering state, the coming of the time for their perfect development; the more important plant is in such case replaced by the plant of lesser pretension, until the conditions of perfect growth have again returned for the former.—*H. Hanstein—Journal for Agriculture*, IX. year, p. 270.

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