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It is with great pleasure that I receive the permission to address so distinguished and enlightened an Audience on the subject of Agricultural Chemistry.

That any thing which I am able to bring forward, should be thought worthy the attention of the Board of Agriculture, I consider as an honour; and I shall endeavour to prove my gratitude, by employing every exertion to illustrate this department of knowledge, and to point out its uses.

In attempting these objects, the peculiar state of the enquiry presents many difficulties to a Lecturer. Agricultural Chemistry has not yet received a regular and systematic form. It has been pursued by competent experimenters for a short time only; the doctrines have not as yet been collected into any elementary treatise; and on an occasion when I am obliged to trust so much to my own arrangements, and to my own limited information, I cannot but feel diffident as to the interest that may be excited, and doubtful of the success of the undertaking. I know, however, that your candour will induce you not to expect any thing like a finished work upon a science as yet in its infancy; and I am sure you will receive with indulgence the first attempt made to illustrate it, in a distinct course of public lectures.

Agricultural Chemistry has for its objects all those changes in the arrangements of matter connected with the growth and nourishment of plants; the comparative values of their produce as food; the constitution of soils; the manner in which lands are enriched by manure, or rendered fertile by the different processes of cultivation. Enquiries of such a nature cannot but be interesting and important, both to the theoretical agriculturist, and to the practical farmer. To the first, they are necessary in supplying most of the fundamental principles on which the theory of the art depends.

To the second, they are useful in affording simple and easy experiments for directing his labours, and for enabling him to pursue a certain and systematic plan of improvement.

It is scarcely possible to enter upon any investigation in agriculture without finding it connected, more or less, with doctrines or elucidations derived from chemistry.

If land be unproductive, and a system of ameliorating it is to be attempted, the sure method of obtaining the object is by determining the cause of its sterility, which must necessarily depend upon some defect in the constitution of the soil, which may be easily discovered by chemical analysis.

Some lands of good apparent texture are yet sterile in a high degree; and common observation and common practice afford no means of ascertaining the cause, or of removing the effect. The application of chemical tests in such cases is obvious; for the soil must contain some noxious principle which may be easily discovered, and probably easily destroyed.

Are any of the salts of iron present? they may be decomposed by lime. Is there an excess of siliceous sand? the system of improvement must depend on the application of clay and calcareous matter. Is there a defect of calcareous matter? the remedy is obvious. Is an excess of vegetable matter indicated? it may be removed by liming, paring, and burning. Is there a deficiency of vegetable matter? it is to be supplied by manure.

A question concerning the different kinds of limestone to be employed in cultivation often occurs. To determine this fully in the common way of experience, would demand a considerable time, perhaps some years, and trials which might be injurious to crops; but by simple chemical tests the nature of a limestone is discovered in a few minutes; and the fitness of its application, whether as a manure for different soils, or as a cement, determined.

Peat earth of a certain consistence and composition is an excellent manure; but there are some varieties of peats which contain so large a quantity of ferruginous matter as to be absolutely poisonous to plants. Nothing can be more simple than the chemical operation for determining the nature, and the probable uses of a substance of this kind.

There has been no question on which more difference of opinion has existed, than that of the state in which manure ought to be ploughed into the land; whether recent, or when it has gone through the process of fermentation? and this question is still a subject of discussion; but whoever will refer to the simplest principles of chemistry, cannot entertain a doubt on the subject. As soon as dung begins to decompose, it throws off its volatile parts, which are the most valuable and most efficient. Dung which has fermented, so as to become a mere soft cohesive mass, has generally lost from one third to one half of its most useful constituent elements. It evidently should be applied as soon as fermentation begins, that it may exert its full action upon the plant, and lose none of its nutritive powers.*

It would be easy to adduce a multitude of other instances of the same

* No doctrine advanced by Davy has been so generally condemned by practical men as this. While it must be admitted that he carried his views on this subject too far, there can be no doubt that occasionally much nutritive matter is lost by pushing decomposition to an unnecessary extent. The physical characters of the soil and the nature of the crops to be cultivated on it must regulate the degree of decomposition that is proper for the manure. This subject is treated of at length in a note on Farm-yard manure. Lecture VI.—S.

kind; but sufficient I trust has been said to prove, that the connexion of Chemistry with Agriculture is not founded on mere vague speculation, but that it offers principles which ought to be understood and followed, and which in their progression and ultimate results, can hardly fail to be highly beneficial to the community.

A view of the objects in this Course of Lectures, and of the manner in which they are to be treated, will not, I hope, be considered as an improper introduction. It will inform you what you are to expect; it will afford a general idea of the connexion of the different parts of the subject, and of their relative importance; it will enable me to give some historical details of the progress of this branch of knowledge, and to reason from what has been ascertained, concerning what remains to be investigated and discovered.

The phenomena of vegetation must be considered as an important branch of the science of organized nature; but though exalted above inorganic matter, vegetables are yet in a great measure dependent for their existence upon its laws. They receive their nourishment from the external elements; they assimilate it by means of peculiar organs; and it is by examining their physical and chemical constitution, and the substances and powers which act upon them, and the modifications which they undergo, that the scientific principles of Agricultural Chemistry are obtained.

According to these ideas, it is evident that the study ought to be commenced by some general enquiries into the composition and nature of material bodies, and the laws of their changes. The surface of the earth, the atmosphere, and the water deposited from it, must either together or separately afford all the principles concerned in vegetation; and it is only by examining the chemical nature of these principles, that we are capable of discovering what is the food of plants, and the manner in which this food is supplied and prepared for their nourishment. The principles of the constitution of bodies, consequently, will form the first subject for our consideration.

By methods of analysis dependent upon chemical and electrical instruments discovered in late times, it has been ascertained that all the varieties of material substances may be resolved into a comparatively small number of bodies, which, as they are not capable of being decompounded, are considered in the present state of chemical knowledge as elements. The bodies incapable of decomposition at present known are forty-seven. * Of these, thirty-eight are metals; seven are inflammable bodies; and two are gases which unite with metals and inflammable bodies, and form with them acids, alkalies, earths, or other analogous compounds. The chemical elements acted upon by attractive powers combine in different aggregates. In their simpler combinations, they produce various crystalline substances, distinguished by the regularity of their forms. In more complicated arrangements they constitute the varieties of vegetable and animal substances, bear the higher character of organization, and are rendered subservient to the purposes of life. And by the influence of heat, light, and electrical powers, there is a constant series of changes; matter assumes new forms, the destruction of one order of beings tends to the conservation of another, solution and consolidation, decay and renovation are connected,

* Now fifty-five. And following the classification in the text these consist of forty-two metals, eight inflammables, and five bodies which unite with metals &c. For notices of these additions see notes to Lecture II.—S.

and whilst the parts of the system continue in a state of fluctuation and change, the order and harmony of the whole remain unalterable.

After a general view has been taken of the nature of the elements, and of the principles of chemical changes, the next object will be the structure and constitution of plants. In all plants there exists a system of tubes or vessels, which in one extremity terminate in roots, and at the other in leaves. It is by the capillary action of the roots that fluid matter is taken up from the soil. The sap in passing upwards becomes denser, and more fitted to deposit solid matter: it is modified by exposure to heat, light, and air in the leaves; descends through the bark, in its progress produces new organized matter; and is thus in its vernal and autumnal flow, the cause of the formation of new parts, and of the more perfect evolution of parts already formed.

In this part of the enquiry I shall endeavour to connect together into a general view, the observation of the most enlightened philosophers who have studied the physiology of vegetation. Those of Grew, Malpighi, Sennebier, Darwin, and, above all, of Mr Knight. He is the latest enquirer into these interesting subjects, and his labours have tended most to illustrate this part of the economy of nature.

The chemical composition of plants has within the last ten years, been elucidated by the experiments of a number of chemical philosophers, both in this, and in other countries; and it forms a beautiful part of general chemistry; it is too extensive to be treated of minutely; but it will be necessary to dwell upon such parts of it, as afford practical inferences.

If the organs of plants be submitted to chemical analysis, it is found that their almost infinite diversity of form, depends upon different arrangements and combinations of a very few of the elements; seldom more than seven or eight belong to them, and three constitute the greatest part of their organized matter; and according to the manner in which these elements are disposed, arise the different properties of the products of vegetation, whether employed as food, or for other purposes and wants of life.

The value and uses of every species of agricultural produce, are most correctly estimated and applied, when practical knowledge is assisted by principles derived from chemistry. The compounds in vegetables really nutritive as the food of animals, are very few; farina or the pure matter of starch, gluten, vegetable jelly, and extract. Of these the most nutritive is gluten, which approaches nearest in its nature to animal matter, and which is the substance that gives to wheat its superiority over other grain. The next in order as to nourishing power, is sugar, then farina; and last of all gelatinous and extractive matters. Simple tests of the relative nourishing powers of the different species of food, are the relative quantities of these substances that they afford by analysis; and though taste and appearance must influence the consumption of all articles in years of plenty, yet they are less attended to in times of scarcity, and on such occasions this kind of knowledge may be of the greatest importance. Sugar and farina or starch, are very similar in composition, and are capable of being converted into each other by simple chemical processes. In the discussion of their relations, I shall detail to you the results of some recent experiments, which will be found possessed of applications both to the economy of vegetation, and to some important processes of manufacture.

All the varieties of substances found in plants, are produced from the sap, and the sap of plants is derived from water, or from the fluids in

the soil, and it is altered by, or combined with principles derived from the atmosphere. The influence of the soil, of water, and of air, will therefore be the next subject of consideration. Soils in all cases consist of a mixture of different finely divided earthy matters; with animal or vegetable substances in a state of decomposition, and certain saline ingredients. The earthy matters are the true basis of the soil; the other parts, whether natural, or artificially introduced, operate in the same manner as manures. Four earths generally abound in soils, the aluminous, the siliceous, the calcareous, and the magnesian. These earths, as I have discovered, consist of highly inflammable metals united to pure air or oxygen; and they are not, as far as we know, decomposed or altered in vegetation.

The great use of the soil is to afford support to the plant, to enable it to fix its roots, and to derive nourishment by its tubes slowly and gradually, from the soluble and dissolved substances mixed with the earths.

That a particular mixture of the earths is connected with fertility, cannot be doubted: and almost all sterile soils are capable of being improved, by a modification of their earthy constituent parts. I shall describe the simplest method as yet discovered of analysing soils, and of ascertaining the constitution and chemical ingredients which appear to be connected with fertility; and on this subject many of the former difficulties of investigation will be found to be removed by recent enquiries.

The necessity of water to vegetation, and the luxuriancy of the growth of plants connected with the presence of moisture in the southern countries of the old continent, led to the opinion so prevalent in the early schools of philosophy, that water was the great productive element, the substance from which all things were capable of being composed, and into which they were finally resolved. The "ἀριστον μεν ὑδωρ" of the poet, "water is the noblest," seems to have been an expression of this opinion, adopted by the Greeks from the Egyptians, taught by Thales, and revived by the alchemists in late times. Van Helmont in 1610, conceived that he had proved by a decisive experiment, that all the products of vegetables were capable of being generated from water. His results were shewn to be fallacious by Woodward in 1691; but the true use of water in vegetation was unknown till 1785; when Mr Cavendish made the grand discovery, that it was composed of two elastic fluids or gases, inflammable gas or hydrogen, and vital gas or oxygen.

Air, like water, was regarded as a pure element by most of the ancient philosophers: a few of the chemical enquirers in the sixteenth and seventeenth centuries, formed some happy conjectures respecting its real nature. Sir Kenelm Digby in 1660, supposed that it contained some saline matter, which was an essential food of plants. Boyle, Hooke, and Mayow, between 1665 and 1680, stated, that a small part of it only was consumed in the respiration of animals, and in the combustion of inflammable bodies; but the true statical analysis of the atmosphere is comparatively a recent labour, achieved towards the end of the last century by Scheele, Priestley, and Lavoisier. These celebrated men shewed that its principal elements are two gases, oxygen and azote, of which the first is essential to flame, and to the life of animals, and that it likewise contains small quantities of aqueous vapour, and of carbonic acid gas; and Lavoisier proved that this last body is itself a compound elastic fluid, consisting of charcoal dissolved in oxygen.

Jethro Tull, in his treatise on Horse-hoeing, published in 1733, advanced the opinion that minute earthy particles supplied the whole nourishment of the vegetable world; that air and water were chiefly useful in

producing these particles from the land; and that manures acted in no other way than in ameliorating the texture of the soil, in short, that their agency was mechanical. This ingenious author of the new system of agriculture having observed the excellent effects produced in farming by a minute division of the soil, and the pulverisation of it by exposure to dew and air, was misled by carrying his principles too far. Duhamel, in a work printed in 1754, adopted the opinion of Tull, and stated that by finely dividing the soil, any number of crops might be raised in succession from the same land. He attempted also to prove, by direct experiments, that vegetables of every kind were capable of being raised without manure. This celebrated horticulturist lived, however, sufficiently long to alter his opinion. The results of his later and most refined observations led him to the conclusion, that no single material afforded the food of plants. The general experience of farmers had long before convinced the unprejudiced of the truth of the same opinion, and that manures were absolutely consumed in the process of vegetation. The exhaustion of soils by carrying off corn crops from them, and the effects of feeding cattle on lands, and of preserving their manure, offer familiar illustrations of the principle; and several philosophical enquirers, particularly Hassenfratz and Saussure, have shown by satisfactory experiments, that animal and vegetable matters deposited in soils are absorbed by plants,* and become a part of their organized matter. But though neither water, nor air, nor earth, supplies the whole of the food of plants, yet they all operate in the process of vegetation. The soil is the laboratory in which the food is prepared. No manure can be taken up by the roots of plants unless water is present; and water or its elements exist in all the products of vegetation. The germination of seeds does not take place without the presence of air or oxygen gas; and in the sunshine vegetables decompose the carbonic acid gas of the atmosphere, the carbon of which is absorbed, and becomes a part of their organized matter, and the oxygen gas, the other constituent, is given off; and in consequence of a variety of agencies, the economy of vegetation is made subservient to the general order of the system of nature.

It is shewn by various researches, that the constitution of the atmosphere has been always the same since the time that it was first accurately analysed; and this must, in a great measure, depend upon the powers of plants to absorb or decompose the putrifying or decaying remains of animals and vegetables, and the gaseous effluvia which they are constantly emitting. Carbonic acid gas is formed in a variety of processes of fermentation and combustion, and in the respiration of animals, and as yet no other process is known in nature by which it can be consumed, except vegetation. Animals produce a substance which appears to be a necessary food of vegetables; vegetables evolve a principle necessary to the existence of animals; and these different classes of beings seem to be thus connected together in the exercise of their living functions, and to a certain extent made to depend upon each other for their existence. Water is raised from the ocean, diffused through the air, and poured down upon the soil, so as to be applied to the purposes of life. The different parts of the atmosphere are mingled together by winds or changes of temperature, and successively brought in contact with the surface of the earth, so as to exert

* It may be fairly questioned whether animal and vegetable matters, as such, are absorbed by plants. It is rather shewn by the more recent experiments that the products of their decomposition afford food for plants.—S.

their fertilizing influence. The modifications of the soil, and the application of manures are placed within the power of man, as if for the purpose of awakening his industry and of calling forth his powers.

The theory of the general operation of the more compound manures may be rendered very obvious by simple chemical principles; but there is still much to be discovered with regard to the best methods of rendering animal and vegetable substances soluble; with respect to the processes of decomposition, how they may be accelerated or retarded, and the means of producing the greatest effects from the materials employed: these subjects will be attended to in the Lecture on Manures.

Plants are found by analysis to consist principally of charcoal and aeriform matter. They give out by distillation volatile compounds, the elements of which are pure air, inflammable air, coally matter, and azote, or that elastic substance which forms a great part of the atmosphere, and which is incapable of supporting combustion. These elements they gain either by their leaves from the air, or by their roots from the soil. All manures from organized substances contain the principles of vegetable matter, which during putrefaction are rendered either soluble in water or aeriform—and in these states they are capable of being assimilated to the vegetable organs. No one principle affords the pabulum of vegetable life; it is neither charcoal nor hydrogen, nor azote nor oxygen alone; but all of them together in various states and various combinations. Organic substances as soon as they are deprived of vitality, begin to pass through a series of changes which ends in their complete destruction, in the entire separation and dissipation of the parts. Animal matters are the soonest destroyed by the operation of air, heat, and light. Vegetable substances yield more slowly, but finally obey the same laws. The periods of the application of manures from decomposing animal and vegetable substanccs depend upon the knowledge of these principles, and I shall be able to produce some new and important facts founded upon them, which I trust will remove all doubt from this part of agricultural theory.

The chemistry of the more simple manures; the manures which act in very small quantities, such as gypsum, alkalies, and various saline substances, has hitherto been exceedingly obscure. It has been generally supposed that these materials act in the vegetable economy in the same manner as condiments or stimulants in the animal economy, and that they render the common food more nutritive. It seems, however, a much more probable idea, that they are actually a part of the true food of plants, and that they supply that kind of matter to the vegetable fibre, which is analogous to the bony matter in animal structures.*

The operation of gypsum, it is well known, is extremely capricious in this country, and no certain data have hitherto been offered for its application.

There is, however, good ground for supposing that the subject will be fully elucidated by chemical enquiry. Those plants which seem most benefitted by its application, are plants which always afford it on analysis. Clover and most of the artificial grasses, contain it, but it exists in very minute quantity only in barley, wheat, and turnips. Many peat ashes which are sold at a considerable price, consist in great part of gypsum, with

* It is interesting to observe, in this and other passages of the Lectures, the germ of the doctrine of the Inorganic constituents of plants—a doctrine to which the labours of Sprengel contributed so largely, and on which Liebeg still more recently has thrown so much light.—S.

little iron, and the first seems to be their most active ingredient. I have examined several of the soils to which these ashes are successfully applied, and I have found in them no sensible quantity of gypsum. In general, cultivated soils contain sufficient of this substance for the use of the grasses; in such cases, its application cannot be advantageous. For plants require only a certain quantity of manure; an excess may be detrimental, and cannot be useful.

The theory of the operation of alkaline substances, is one of the parts of the chemistry of agriculture, most simple and distinct. They are found in all plants, and therefore may be regarded as amongst their essential ingredients. From their powers of combination likewise, they may be useful in introducing various principles into the sap of vegetables, which may be subservient to their nourishment.

The fixed alkalies which were formerly regarded as elementary bodies, it has been my good fortune to decompose. They consist of pure air,* united to highly inflammable metallic substances; but there is no reason to suppose that they are reduced into their elements in any of the processes of vegetation.

In this part of the course I shall dwell at considerable length on the important subject of lime, and I shall be able to offer some novel views.

Slacked lime was used by the Romans for manuring the soil in which fruit trees grew. This we are informed by Pliny. Marle had been employed by the Britons and the Gauls from the earliest times, as a top dressing for land. But the precise period in which burnt lime first came into general use in the cultivation of land is, I believe, unknown. The origin of the application from the early practices is sufficiently obvious; a substance which had been used with success in gardening, must have been soon tried in farming; and in countries where marle was not to be found, calcined limestone would be naturally employed as a substitute.

The elder writers on agriculture had no correct notions of the nature of lime, limestone, and marle, or of their effects; and this was the necessary consequence of the imperfection of the chemistry of the age. Calcareous matter was considered by the alchemists as a peculiar earth, which in the fire became combined with inflammable acid; and Evelyn and Hartlib, and, still later, Lisle, in their works on husbandry, have characterised it merely as a hot manure of use in cold lands. It is to Dr. Black, of Edinburgh, that our first distinct rudiments of knowledge on the subject are owing. About the year 1755, this celebrated professor proved, by the most decisive experiments, that limestone and all its modifications, marbles, chalks, and marles, consist principally of a peculiar earth united to an aerial acid: that the acid is given out in burning, occasioning a loss of more than 40 per cent., and the lime in consequence becomes caustic.

These important facts immediately applied with equal certainty to the explanation of the uses of lime, both as a cement and as a manure. As a cement, lime applied in its caustic state acquires its hardness and durability, by absorbing the aerial (or as it has been since called carbonic) acid, which always exists in small quantities in the atmosphere, as it were again limestone.

Chalks, calcareous marles, or powdered lime-stones, act merely by forming an useful earthy ingredient of the soil, and their efficacy is proportioned to the deficiency of calcareous matter, which in larger or smaller quantities seems to be an essential ingredient of all fertile soils; necessary

* Oxygen.—S.

perhaps to their proper texture, and as an ingredient in the organs of plants.

Burnt lime, in its first effect, acts as a decomposing agent upon animal or vegetable matter, and seems to bring it into a state on which it becomes more rapidly a vegetable nourishment; gradually, however, the lime is neutralized by carbonic acid, and converted into a substance analogous to chalk; but in this case it more perfectly mixes with the other ingredients of the soil, is more generally diffused and finely divided; and it is probably more useful to land than any calcareous substance in its natural state.

The most considerable fact made known with regard to lime-stone within the last few years, is owing to Mr. Tennant. It had been long known that a particular species of lime-stone found in different parts of the North of England, when applied in its burnt and slacked state to land in considerable quantities, occasioned sterility, or considerably injured the crops for many years. Mr. Tennant in 1800, by a chemical examination of this species of lime-stone, ascertained, that it differed from common lime-stones by containing magnesian earth; and by several experiments he proved that this earth was prejudicial to vegetation, when applied in large quantities in its caustic state. Under common circumstances, the lime from the magnesian lime-stone is, however, used in moderate quantities upon fertile soils in Leicestershire, Derbyshire, and Yorkshire, with good effect; and it may be applied in greater quantities to soils containing very large proportions of vegetable matter. Magnesia when combined with carbonic acid gas, seems not to be prejudicial to vegetation, and in soils rich in manure, it is speedily supplied with this principle from the decomposition of the manure.

After the nature and operation of manures have been discussed, the next, and the last subject for our consideration, will be some of the operations of husbandry capable of elucidation by chemical principles.

The chemical theory of fallowing is very simple. Fallowing affords no new source of riches to the soil. It merely tends to produce an accumulation of decomposing matter, which in the common course of crops would be employed as it is formed, and it is scarcely possible to imagine a single instance of a cultivated soil, which can be supposed to remain fallow for a year with advantage to the farmer. The only cases where this practice is beneficial seems to be in the destruction of weeds, and for cleansing foul soils.

The chemical theory of paring and burning, I shall discuss fully in this part of the course.

It is obvious that in all cases it must destroy a certain quantity of vegetable matter, and must be principally useful in cases in which there is an excess of this matter in soils. Burning, likewise renders clays less coherent, and in this way greatly improves their texture, and causes them to be less permeable to water.

The instances in which it must be obviously prejudicial, are those of sandy dry siliceous soils, containing little animal or vegetable matter. Here it can only be destructive, for it decomposes that on which the soil depends for its productiveness.

The advantages of irrigation, though so lately a subject of much attention, were well known to the ancients; and more than two centuries ago the practice was recommended to the farmers of our country by Lord Bacon; "meadow-watering," according to the statements of this illustrious personage, (given in his Natural History, in the article Vegetation,) acts not only by supplying useful moisture to the grass; but likewise the water carries nourishment dissolved in it, and defends the roots from the effects of cold.

No general principles can be laid down respecting the comparative merit of the different systems of cultivation, and the different systems of crops adopted in different districts, unless the chemical nature of the soil, and the physical circumstances to which it is exposed are fully known. Stiff coherent soils are those most benefitted by minute division and aeration, and in the drill system of husbandry, these effects are produced to the greatest extent; but still the labour and expense connected with its application in certain districts, may not be compensated for by the advantages produced. Moist climates are best fitted for raising the artificial grasses, oats, and broad-leaved crops; stiff aluminous soils, in general, are most adapted for wheat crops, and calcareous soils produce excellent sain-foin and clover.

Nothing is more wanting in agriculture, than experiments in which all the circumstances are minutely and scientifically detailed. This art will advance with rapidity in proportion as it becomes exact in its methods. As in physical researches all the causes should be considered; a difference in the results may be produced, even by the fall of half an inch of rain more or less in the course of a season, or a few degrees of temperature, or even by a slight difference in the sub-soil, or in the inclination of the land.

Information collected after views of distinct enquiry, would necessarily be more accurate, and more capable of being connected with the general principles of science; and a few histories of the results of truly philosophical experiments in agricultural chemistry, would be of more value in enlightening and benefitting the farmer, than the greatest possible accumulation of imperfect trials, conducted merely in the empirical spirit. It is no unusual occurrence for persons who argue in favour of practice and experience, to condemn generally all attempts to improve agriculture by philosophical enquiries and chemical methods. That much vague speculation may be found in the works of those who have lightly taken up agricultural chemistry, it is impossible to deny. It is not uncommon to find a number of changes rung upon a string of technical terms, such as oxygen, hydrogen, carbon and azote, as if the science depended upon words, rather than upon things. But this is in fact an argument for the necessity of the establishment of just principles of chemistry on the subject. Whoever reasons upon agriculture, is obliged to recur to this science. He feels that it is scarcely possible to advance a step without it; and if he is satisfied with insufficient views, it is not because he prefers them to accurate knowledge, but generally because they are more current. If a person journeying in the night wishes to avoid being led astray by the ignis fatuus, the most secure method is to carry a lamp in his own hand.

It has been said, and undoubtedly with great truth, that a philosophical chemist would most probably make a very unprofitable business of farming; and this certainly would be the case, if he were a mere philosophical chemist; and unless he had served his apprenticeship to the practice of the art, as well as to the theory. But there is reason to believe, that he would be a more successful agriculturist than a person equally uninitiated in farming, but ignorant of chemistry altogether; his science, as far as it went, would be useful to him. But chemistry is not the only kind of knowledge required, it forms a small part of the philosophical basis of agriculture; but it is an important part, and whenever applied in a proper manner must produce advantages.

In proportion as science advances all the principles become less complicated, and consequently more useful. And it is then that their applica-

tion is most advantageously made to the arts. The common labourer can never be enlightened by the general doctrines of philosophy, but he will not refuse to adopt any practice, of the utility of which he is fully convinced, because it has been founded upon these principles. The mariner can trust to the compass, though he may be wholly unacquainted with the discoveries of Gilbert on magnetism, or the refined principles of that science developed by the genius of Æpinus. The dyer will use his bleaching liquor, even though he is perhaps ignorant, not only of the constitution, but even of the name of the substance on which its powers depend. The great purpose of chemical investigation in Agriculture, ought undoubtedly to be the discovery of improved methods of cultivation. But to this end, general scientific principles and practical knowledge, are alike necessary. The germs of discovery are often found in rational speculations; and industry is never so efficacious as when assisted by science.

It is from the higher classes of the community, from the proprietors of land; those who are fitted by their education to form enlightened plans, and by their fortunes to carry such plans into execution; it is from these that the principles of improvement must flow to the labouring classes of the community; and in all cases the benefit is mutual; for the interest of the tenantry must be always likewise the interest of the proprietors of the soil. The attention of the labourer will be more minute, and he will exert himself more for improvement when he is certain he cannot deceive his employer, and has a conviction of the extent of his knowledge. Ignorance in the possessor of an estate of the manner in which it ought to be treated, often leads either to inattention or injudicious practices in the tenant or the bailiff. "*Agrum pessimum mulctari cujus Dominus non docet sed audit villicum.*"

There is no idea more unfounded than that a great devotion of time, and a minute knowledge of general chemistry is necessary for pursuing experiments on the nature of soils or the properties of manures. Nothing can be more easy than to discover whether a soil effervesces, or changes colour by the action of an acid, or whether it burns when heated; or what weight it loses by heat: and yet these simple indications may be of great importance in a system of cultivation. The expence connected with chemical inquiries is extremely trifling; a small closet is sufficient for containing all the materials required. The most important experiments may be made by means of a small portable apparatus; a few phials, a few acids, a lamp and a crucible, are all that are necessary, as I shall endeavour to prove to you, in the course of these lectures.*

It undoubtedly happens in agricultural chemical experiments con-

* It is by no means difficult to ascertain several important particulars regarding soils, manures, &c., and to do so requires neither complicated nor expensive apparatus. But it ought to be more generally known than it is, that accurate chemical analysis of soils, manures, crops, &c., can be performed well only by experienced chemists. Few indeed are the cases where the practical farmer or even the amateur has had the training necessary to fit him for such processes as the separation and estimation of substances occurring only in minute quantities, but nevertheless of the greatest importance to be determined.

Such general examinations of soils as that recommended by Mr Rham, and a number of other easy operations may be readily performed by those who have had no regular training in a laboratory.—Such investigations frequently render more elaborate ones unnecessary, and even should they fail in this they form an excellent introduction to more difficult operations.—S.

ducted after the most refined theoretical views, that there are many instances of failure, for one of success; and this is inevitable from the capricious and uncertain nature of the causes that operate, and from the impossibility of calculating on all the circumstances that may interfere; but this is far from proving the inutility of such trials; one happy result which can generally improve the methods of cultivation is worth the labour of a whole life; and an unsuccessful experiment well observed, must establish some truth, or tend to remove some prejudice.

Even considered merely as a philosophical science, this department of knowledge is highly worthy of cultivation. For what can be more delightful than to trace the forms of living beings and their adaptations and peculiar purposes; to examine the progress of inorganic matter in its different processes of change, till it attain its ultimate and highest destination; its subserviency to the purposes of man.

Many of the sciences are ardently pursued, and considered as proper objects of study for all refined minds, merely on account of the intellectual pleasure they afford; merely because they enlarge our views of nature, and enable us to think more correctly with respect to the beings and objects surrounding us. How much more then is this department of enquiry worthy of attention, in which the pleasure resulting from the love of truth and of knowledge is as great as in any other branch of philosophy, and in which it is likewise connected with much greater practical benefits and advantages. "*Nihil est melius, nihil uberius, nihil homine libero dignius.*"

Discoveries made in the cultivation of the earth, are not merely for the time and country in which they are developed, but they may be considered as extending to future ages, and as ultimately tending to benefit the whole human race; as affording subsistence for generations yet to come; as multiplying life, and not only multiplying life, but likewise providing for its enjoyment.

LECTURE II.

OF THE GENERAL POWERS OF MATTER WHICH INFLUENCE VEGETATION—OF GRAVITATION, OF COHESION, OF CHEMICAL ATTRACTION, OF HEAT, OF LIGHT, OF ELECTRICITY, PONDERABLE SUBSTANCES, ELEMENTS OF MATTER, PARTICULARLY THOSE FOUND IN VEGETABLES, LAWS OF THEIR COMBINATIONS AND ARRANGEMENTS.

THE great operations of the farmer are directed towards the production or improvement of certain classes of vegetables; they are either mechanical or chemical, and are, consequently, dependant upon the laws which govern common matter. Plants themselves are, to a certain extent, submitted to these laws; and it is necessary to study their effects, both in considering the phenomena of vegetation, and the cultivation of the vegetable kingdom.

One of the most important properties belonging to matter is *gravitation*, or the power by which masses of matter are attracted towards each other. It is in consequence of gravitation that bodies thrown into the atmosphere fall to the surface of the earth, and that the different parts of the globe are preserved in their proper positions. Gravity is exerted in proportion to the quantity of matter. Hence all bodies placed above the surface of the earth fall to it in right lines, which if produced would pass through its centre; and a body falling near a high mountain, is a little bent out of the perpendicular direction by the attraction of the mountain, as has been shown by the experiments of Dr. Maskelyne on Schehallien.

Gravitation has a very important influence on the growth of plants; and it is rendered probable, by the experiments of Mr Knight, that they owe the peculiar direction of their roots and branches almost entirely to this force.

That gentleman fixed some seeds of the garden bean on the circumference of a wheel, which in one instance was placed vertically, and in the other horizontally, and made to revolve, by means of another wheel worked by water, in such a manner, that the number of the revolutions could be regulated; the beans were supplied with moisture, and were placed under circumstances favourable to germination. The greatest velocity of motion given to the wheel was such, that it performed 250 revolutions in a minute. It was found that in all cases the beans grew, and that the direction of the roots and stems was influenced by the motion of the wheel. When the centrifugal force was made superior to the force of gravitation, which was supposed to be done when the vertical wheel performed 150 revolutions in a minute, all the radicles, in whatever way they were protruded from the position of the seeds, turned their points outwards from the circumference of the wheel, and in their subsequent growth receded nearly at right angles from its axis; the germens, on the contrary, took the

opposite direction, and in a few days their points all met in the centre of the wheel. (Fig. 2.)

When the centrifugal force was made merely to modify the force of gravitation in the horizontal wheel, where the greatest velocity of revolution was given, the radicles pointed downwards about ten degrees below, and the germens as many degrees above the horizontal line of the wheel's motion; (fig. 1.) and the deviation from the perpendicular was less in proportion, as the motion was less rapid.

Fig. 1.

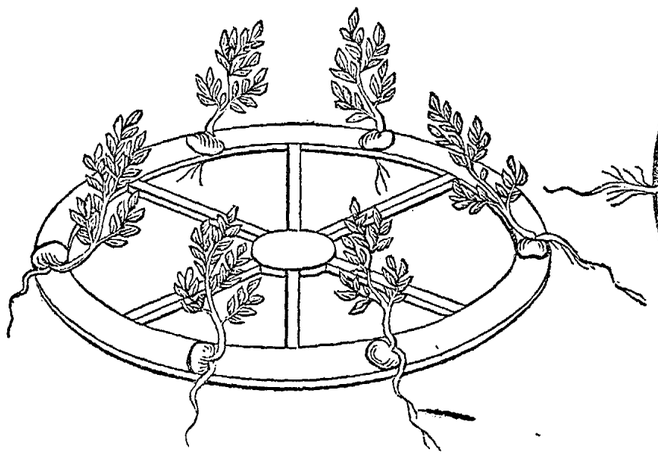
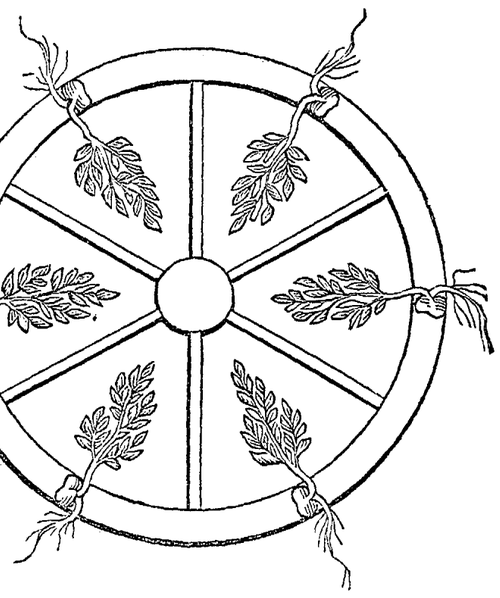


Fig. 2.



These facts afford a rational solution of this curious problem, respecting which different philosophers have given such different opinions; some referring it to the nature of the sap, as De la Hire, others, as Darwin, to the living powers of the plant, and the stimulus of air upon the leaves, and of moisture upon the roots. The effect is now shewn to be connected with mechanical causes; and there seems no other power in nature to which it can with propriety be referred but gravity, which acts universally, and which must tend to dispose the parts to take a uniform direction.*

If plants in general owe their perpendicular direction to gravity, it is evident that the number of plants upon a given part of the earth's circumference, cannot be increased by making the surface irregular, as some persons have supposed. Nor can more stalks rise on a hill than on a spot

* Vegetable physiologists still concur, to a great extent, with this opinion; but, in consequence of numerous observations and experiments, their views have been considerably modified and enlarged. The most important of the opinions now entertained, on this subject, will be found ably stated in Lindley's Introduction to Botany, p. 333, from which chiefly the following particulars are condensed:—

1st, The roots of such plants as grow in the ground do not descend in consequence of their attraction for moisture, nor do their stems ascend in consequence of an attraction for the atmosphere. This conclusion is clearly indicated by an ingenious experiment of Dutrochet. He placed seeds of the kidney bean in holes bored through the bottom of a box, laid a layer of moist earth above them, and suspended the box at a distance of eighteen feet above the ground. The roots in place of ascending into the moist earth, grew downwards into the air, shrivelled and died—the stems, on the contrary, grew upwards into the earth and also perished.

2d, Gravity is not the immediate, but the remote cause of the directions taken by plants. This conclusion Dutrochet deduces from an experiment on the seed of the misletoe, a parasite; he "made a seed of misletoe germinate on a thread:

equal to its base; for the slight effect of the attraction of the hill, would be only to make the plants deviate a very little from the perpendicular. Where horizontal layers are pushed forth, as in certain grasses, particularly such as the fiorin, lately brought into notice by Dr. Richardson, more food may, however, be produced upon an irregular surface; but the principle seems to apply strictly to corn crops.

The direction of the radicles and germens is such, that both are supplied with food, and acted upon by those external agents which are necessary for their developement and growth. The roots come in contact

he then glued it upon one of the points of a fine needle, fixed like that of a compass, balancing it by a bit of wax at the other end of the needle: he next placed a piece of wood at about half a line distance from the radicle; and then covered the whole apparatus with a glass, placed under such conditions that it was impossible that any cause could move the needle: in five days the embryo began to bend, and direct its radicle towards the bit of wood, without the needle changing its position, although it was extremely moveable upon its centre: in two days more, the radicle was directed perpendicularly to the bit of wood with which it had come in contact, and still the needle had not stirred. This proves," says Dutrochet, "that the direction of the radicle of the misletoe, towards a neighbouring body, is not the immediate result of any attraction on the part of such a body; but that it is the result of a spontaneous movement of the embryo, in consequence of the attracting influence exerted upon its radicle, which is thus the mediate or occasional cause of the phenomenon. It is obvious, indeed, that the inflexion of the stem of the embryo of the misletoe could not be due to the immediate attraction on the part of the bit of wood; for an exterior power sufficient to produce this inflexion would much more readily have produced a change in the direction of the needle, to one of whose points the seed was fixed; there can, therefore, be no doubt that the movement was *spontaneous;* that is to say, that it was caused by an internal vital cause, put in action by the influence of an exterior agent. This spontaneous direction of the radicle of the misletoe, under the influence of attraction, proves incontestably that attraction only influenced its nervous powers, and not its ponderable matter: and the same is undoubtedly the case with terrestrial plants."

3d, Parasites do not obey the attraction of the earth, but grow at right angles to the surface, to which they are attached. This is shewn by attaching their seeds to plants on which they can line, so as to cause their plumules to grow upwards, downwards, or horizontally with respect to the earth's surface. When attached to bodies incapable of affording them nourishment, they are still found to commence growing at right angles to the surface of such bodies.

4th, The oblique direction of branches of trees is accounted for, by a combination of these principles. The tree is fitted to grow in the soil, and its stem is accordingly directed upwards, or at right angles to the horizontal plane. Branches given off by the stem are so to speak parasites, and would grow at right angles to the stem, were they not more or less affected by the same influence that directs the stem, and thus compelled to assume the diagonal, or to grow outwards and upwards.

5th, That light is an important agent in causing stems, leaves, and other green parts of plants to assume an upward direction. This is shewn by the well known tendency that leaves have to grow towards the light. When roots, as they sometimes do, become green at the tips, they seek the light and turn upwards, while stems and other organs usually found above ground, are not coloured green when found underground.

The direction of leaves seems to be chiefly influenced by colour. In general the upper surface is more highly polished and coloured of a deeper green than the under surface, and, in that case, the former is directed to the sky, the latter to the earth. In some cases both sides are equally polished and green, and then the edge of the leaf is directed to the sky; and when it occurs as in the Amophila arenaria (bent grass), that the upper side is roughest and palest, the leaf turns over, bringing the paler side downwards.—S.

with the fluids in the ground; the leaves are exposed to light and air; and the same grand law which preserves the planets in their orbits, is thus essential to the functions of vegetable life.

When two pieces of polished glass are pressed together they adhere to each other, and it requires some force to separate them. This is said to depend upon the *attraction of cohesion*. The same attraction gives the globular form to drops of water, and enables fluids to rise in capillary tubes;* and hence it is sometimes called *capillary attraction*. This attraction, like gravitation, seems common to all matter, and may be a modification of the same general force; like gravitation, it is of great importance in vegetation. It preserves the forms of aggregation of the parts of plants, and it seems to be a principal cause of the absorption of fluids by their roots.

If some pure magnesia, the calcined magnesia of druggists, be thrown into distilled vinegar, it gradually dissolves. This is said to be owing to *chemical attraction*, the power by which different species of matter tend to unite into one compound. Various kinds of matter unite with different degrees of force; thus sulphuric acid and magnesia unite with more readiness than distilled vinegar and magnesia; and if sulphuric acid be poured into a mixture of vinegar and magnesia, in which the acid properties of the vinegar have been destroyed by the magnesia, the vinegar will be set free, and the sulphuric acid will take its place. This chemical attraction is likewise called *chemical affinity*. It is active in most of the phenomena of vegetation. The sap consists of a number of ingredients, dissolved in water by chemical attraction; and it appears to be in consequence of the operation of this power, that certain principles derived from the sap are united to the vegetable organs. By the laws of chemical attraction, different products of vegetation are changed, and assume new forms: the food of plants is prepared in the soil; vegetable and animal remains are changed by the action of air and water, and made fluid or aeriform; rocks are broken down and converted into soils; and soils are more finely divided and fitted as receptacles for the roots of plants.

The different powers of attraction tend to preserve the arrangements of matter, or to unite them in new forms. If there were no opposing powers, there would soon be a state of perfect quiescence in nature, a kind of eternal sleep in the physical world. Gravitation is continually counteracted by mechanical agencies, by projectile motion, or the centrifugal force; and their joint agencies occasion the motion of the heavenly bodies. Cohesion and chemical attraction are opposed by the *repulsive energy* of *heat*, and the harmonious cycle of terrestrial changes is produced by their mutual operations.

Heat is capable of being communicated from one body to other bodies; and its common effect is to expand them, to enlarge them in all their dimensions. This is easily exemplified. A solid cylinder of metal after being heated will not pass through a ring barely sufficient to receive it when cold. When water is heated in a globe of glass having a long slender neck, it rises in the neck; and if heat be applied to air confined

* Cohesion and capillary attraction agree in acting at insensible distances, but differ in this respect, that while cohesion exists only between particles of the *same* kind of matter, capillary attraction takes place between different kinds of matter. Thus it is by cohesion that the particles of any solid or liquid body are held together, and it is by capillary attraction that water, mercury, &c., rise in very fine tubes, or enter into the cavities of a sponge or porous body.—S.

in such a vessel inverted above water, it makes its escape from the vessel, and passes through the water. Thermometers are instruments for measuring degrees of heat by the expansion of fluids in narrow tubes. Mercury is generally used, of which 100,000 parts at the freezing point of water become 101,835* parts at the boiling point, and on Fahrenheit's scale these parts are divided into 180 degrees. Solids, by a certain increase of heat become fluids, and fluids gases, or elastic fluids. Thus ice is converted by heat into water, and by still more heat it becomes steam: and heat disappears, or, as it is called, is rendered *latent* during the conversion of solids into fluids, or fluids into gases, and reappears or becomes sensible when gases become fluids, or fluids solids; hence cold is produced during evaporation, and heat during the condensation of steam.

There are a few exceptions to the law of expansion of bodies by heat, which seem to depend either upon some change in their chemical constitution, or on their becoming crystallized. Clay contracts by heat, which seems to be owing to its giving off water. Cast iron and antimony, when melted, crystallize in cooling and expand. Ice is much lighter than water. Water expands a little even before it freezes, and it is of the greatest density at about 41° or 42°, [at 39° according to Hallström.—S] the freezing point being 32°; and this circumstance is of considerable importance in the general economy of nature. The influence of the changes of seasons and of the position of the sun on the phenomena of vegetation, demonstrates the effects of heat on the functions of plants. The matter absorbed from the soil must be in a fluid state to pass into their roots, and when the surface is frozen they can derive no nourishment from it. The activity of chemical changes likewise is increased by a certain increase of temperature, and even the rapidity of the ascent of fluids by capillary attraction.

This last fact is easily shown by placing in each of two wine glasses a similar hollow stalk of grass, so bent as to discharge any fluid in the glasses slowly by capillary attraction; if hot water be in one glass, and cold water in the other, the hot water will be discharged much more rapidly than the cold water. The fermentation and decomposition of animal and vegetable substances require a certain degree of heat, which is consequently necessary for the preparation of the food of plants; and as evaporation is more rapid in proportion as the temperature is higher, the superfluous parts of the sap are most readily carried off at the time its ascent is quickest.

Two opinions are current respecting the nature of heat. By some philosophers it is conceived to be a peculiar subtile fluid, of which the particles repel each other, but have a strong attraction for the particles of other matter. By others it is considered as a motion or vibration of the particles of matter, which is supposed to differ in velocity in different cases, and thus to produce the different degrees of temperature.† Whatever decision be ultimately made respecting these opinions, it is certain that there is matter moving in the space between us and the heavenly bodies capable of communicating heat; the motions of which are rectilineal: thus the solar rays produce heat in acting on the surface of the

* 100,000 parts of Mercury, at 32° become 101,8018 at 212° or increase $\frac{1}{555}$ of their volume, according to Dulong and Petit.

† Those who hold the vibracular hypothesis rather maintain that heat is the result of waves or vibrations of an extremely attenuated ether, that pervades all space and matter.

earth. The beautiful experiments of Dr. Herschel have shewn that there are *rays* transmitted from the sun which do not illuminate; and which yet produce *more heat* than the *visible rays;* and Mr. Ritter and Dr. Wollaston have shown that there are *other invisible* rays distinguished by their *chemical* effects.

The different influences of the different solar rays on vegetation have not yet been studied; but it is certain that the rays exercise an influence independent of the heat they produce. * Thus plants kept in the dark in a hot-house grow luxuriantly, but they never gain their natural colours; their leaves are white or pale, and their juices watery and peculiarly saccharine. †

When a piece of sealing-wax is rubbed by a woollen cloth, it gains the power of attracting light bodies, such as feathers or ashes In this state it is said to be *electrical;* and if a metallic cylinder, placed upon a rod of glass, is brought in contact with the sealing-wax, it likewise gains the momentary power of attracting light bodies, so that electricity like heat is communicable. When two light bodies receive the same electrical influence, or are electrified by the same body, they repel each other. When one of them is acted on by sealing-wax, and the other by glass that has been rubbed by woollen, they attract each other; hence it is said, that bodies similarly electrified repel each other, and bodies dissimi-

* Some interesting experiments on the effects produced on plants grown under glass of different colours, have lately been undertaken at the instance of the British Association. The results have not been fully reported, but the subject merits attention, and will elucidate some important points in vegetable physiology.

† Before passing to a new subject, it seems necessary to refer to another doctrine of heat, important to the agriculturist, viz. *Radiation*, or the passage of heat in strait lines (radii) from the surface of heated bodies.

The sensation of heat which we perceive when opposite to a bright fire, is not the result of heat conducted to our bodies through the particles of intervening air; for were a hot ball suspended under the exhausted receiver of an air pump, a thermometer placed outside would be sensibly affected. In like manner the heat which the sun imparts is communicated by radiation. It has been ascertained by experiment, that bodies differ much in respect to their radiating power, and that those bodies that radiate well also absorb radiant heat well. Polished metallic bodies radiate ill and absorb ill. Rough surfaces, dark coloured bodies, and especially organic substances radiate and absorb well. Hence it follows that dark coloured soils containing much organic matter, will be more rapidly and more highly heated by the direct rays of the sun than lighter coloured and less organic ones, and that they will lose their heat with as much facility as they acquire it. Schübler found that by exposing at the same time sand of black, grey, and white colours, to the rays of the sun, the first rose $46\frac{1}{2}^{\circ}$ the second $35\frac{1}{2}^{\circ}$ and the third 33°.

On the principle of radiation, too, the deposition of dew and hoar-frost is explained. All bodies are believed to be continually radiating. When a body receives more rays than it emits, its temperature rises, as is the case with the earth during sunshine. When a body gives off more rays than it receives, its temperature falls, as is the case with the earth during a cloudless night. No dew is deposited in cloudy nights, for the rays thrown off by the earth are returned by the clouds, and the temperature of the air is maintained. On a clear night, however, the heat radiated from the earth is lost in space, the temperature of grass, herbage, &c., falls, and the vapour that exists in the stratum of air next to them is deposited on the cold surfaces as dew, or hoar-frost, according to the temperature.—On the subject of radiation, the student may consult Leslie's Essays on Heat—Wells on Dew—Daniell's Meteorology, &c.

larly electrified attract each other; and the electricity of glass is called vitreous or positive electricity, and that of sealing-wax resinous or negative electricity.

When of two bodies made to rub each other one is found positively electrified, the other is always found negatively electrified, and, as in the common electrical machine, these states are capable of being communicated to metals placed upon rods or pillars of glass. Electricity is produced likewise by the contact of bodies;* thus a piece of zinc and of silver give a slight electrical shock when they are made to touch each other, and to touch the tongue; and when a number of plates of copper and zinc, one hundred for instance, are arranged in a pile with cloths moistened in salt and water, in the order of zinc, copper, moistened cloth, zinc, copper, moistened cloth, and so on, they form an electrical battery which will give strong shocks and sparks, and which is possessed of remarkable chemical powers. The luminous phenomena produced by common electricity are well known. It would be improper to dwell upon them in this place. They are the most impressive effects occasioned by this agent; and they offer illustrations of lightning and thunder.

Electrical changes are constantly taking place in nature, on the surface of the earth and in the atmosphere; but as yet the effects of this power in vegetation have not been correctly estimated. It has been shewn by experiments made by means of the voltaic battery (the instrument composed of zinc, copper, and water), that compound bodies in general are capable of being decomposed by electrical powers, and it is probable, that the various electrical phenomena occurring in our system, must influence both the germination of seeds and the growth of plants. I found that corn sprouted much more rapidly in water positively electrified by the Voltaic instrument than in water negatively electrified; and experiments made upon the atmosphere shew that clouds are usually negative; and as when a cloud is in one state of electricity the surface of the earth beneath is brought into the opposite state, it is probable that in common cases the surface of the earth is positive.

Different opinions are entertained amongst scientific men respecting the nature of electricity; by some, the phenomena are conceived to depend upon a single subtile fluid in excess in the bodies said to be positively electrified, in deficiency in the bodies said to be negatively electrified. A second class suppose the effects to be produced by two different fluids, called by them the vitreous fluid and the resinous fluid; and others regard them as affections or motions of matter, or an exhibition of attractive powers, similar to those which produce chemical combination and decomposition; but usually exerting their action on masses.

The different powers that have been thus generally described, continually act upon common matter so as to change its form, and produce arrangements fitted for the purposes of life. Bodies are either simple or compound. A body is said to be simple, when it is incapable of being resolved into any other forms of matter. Thus gold or silver, though they may be melted by heat or dissolved in corrosive menstrua, yet are recovered unchanged in their properties, and they are said to be simple bodies. A body is considered as compound, when two or more distinct substances are

* That metallic contact is not essential to voltaic action, has been clearly established by Faraday. It is now generally believed, as was originally maintained by Wollaston, that chemical action is the sole cause by which voltaic electricity is excited.

capable of being produced from it; thus marble is a compound body, for by a strong heat, it is converted into lime, and an elastic fluid is disengaged in the process: and the proof of our knowledge of the true composition of a body is, that it is capable of being reproduced by the same substances as those into which it had been decomposed; thus by exposing lime for a long while to the elastic fluid, disengaged during its calcination, it becomes converted into a substance similar to powdered marble.* The term element has the same meaning as simple or undecompounded body; but it is applied merely with reference to the present state of chemical knowledge. It is probable, that as yet we are not acquainted with any of the true elements of matter; many substances, formerly supposed to be simple, have been lately decompounded, and the chemical arrangement of bodies must be considered as a mere expression of facts, the results of accurate statical experiments.

Vegetable substances in general are of a very compound nature,† and consist of a great number of elements, most of which belong likewise to the other kingdoms of nature, and are found in various forms. Their more complicated arrangements are best understood after their simpler forms of combination have been examined.

The number of bodies which I shall consider as at present undecomposed, are, as was stated in the introductory lecture, two gases that support combustion, seven inflammable bodies, and thirty-eight metals.‡

* Of the composition of a compound body, we may have two kinds of proof, the *Analytic* and *Synthetic*. The analytic consists in resolving the compound into its constituents; the synthetic in causing its elements or constituents to combine, and thus reconstructing the body. Both methods are illustrated in the text. When both proofs can be obtained, it is in the highest degree satisfactory; but, frequently the analytic proof is the only one the chemist can obtain. For although the elementary bodies be taken in the exact proportions necessary, some condition, the knowledge of which science has not yet reached, is awanting, and we are compelled to rest satisfied with the single proof. Although to the cursory reader it appears so, it is not meant to be taught in the text, that it is only when both proofs are attainable, that we are to consider the composition of a body proved. Of the composition of organic bodies, with scarcely a single exception, we derive our information solely from analysis, but the case is different with most inorganic compounds, and this forms, as will be afterwards seen, a most important distinction between organic and inorganic bodies.

† At first sight this statement seems inconsistent with what was stated in the introductory lecture, and also with the doctrine advanced, that "the elements found in vegetables are very few." It is true that with the exception of the small quantities of inorganic matter found in the ashes, vegetables consist of but four—chiefly of three elementary principles. But if we examine a plant we find it composed of a great number of *proximate* principles, and these proximates, though agreeing in the number of their ultimate constituents, still differ in their proportions. And we find also that different plants differ much in the number and proportion of their proximate principles.

‡ Since 1813 several additions have been made to the list of simple substances. In the text they are estimated at 47; the number now amounts to 55. The increase has not arisen from the decomposition of any of those thought to be simple, but from the examination of substances at the time not accurately examined, or entirely unknown. Following the classification of the text, the first group consists of oxygen, and chlorine, placed in it by Davy. Iodine and bromine since discovered, and fluorine, which at that time had not been obtained in a separate state, and which under the name of fluon Davy placed provisionally among the inflammables. The second group now contains eight substances

In most of the inorganic compounds, the nature of which is well known, into which these elements enter, they are combined in definite proportions; so that if the elements be represented by numbers, the proportions in which they combine are expressed either by those numbers, or by some simple multiple of them.

I shall mention in a few words, the characteristic properties of the most important simple substances, and the numbers representing the proportions in which they combine in those cases, where they have been accurately ascertained.

1. OXYGEN forms about one-fifth of the air of our atmosphere. It is an elastic fluid, at all known temperatures. Its specific gravity is to that of air as 10,967 to 10,000 [specific gravity of oxygen 1.1057.—S]. It supports combustion with much more vividness than common air; so that if a small steel wire, or a watch spring, having a bit of inflamed wood attached to it, be introduced into a bottle filled with the gas it burns with great splendour. It is respirable. It is very slightly soluble in water.* The number representing the proportion in which it combines is 15.† It may be made by heating a mixture of the mineral called manganese, and sulphuric acid together, in a proper vessel, or by heating strongly red lead, or red precipitate of mercury.‡

2. CHLORINE, or oxymuriatic gas, is, like oxygen, a permanent elastic fluid. Its colour is yellowish green; its smell is very disagreeable; it is not respirable; it supports the combustion of all the common inflammable bodies except charcoal; its specific gravity is to that of air as 24,677 to 10,000 [specific gravity, 2.449.—S]; it is soluble in about half its volume of water, and its solution in water destroys vegetable colours. Many of the metals (such as arsenic or copper) take fire spontaneously when introduced into a jar or bottle filled with the gas. Chlorine may be procured by heating together a mixture of spirits of salt or muriatic acid, and manganese. The number representing the proportion in which this gas enters into combination is 67 [equivalent 35.42.—S]. §

viz., hydrogen, nitrogen, carbon, sulphur, phosphorus, and boron, placed in it by Davy, together with silicon, which, under the name of silicium, he ranked among the metals, and selenium subsequently discovered. From the group of metals, selenium has been removed, as above noticed; cadmium, lithium. thorium, vanadium, and lantanium have been added, these increasing the number of this group to 42.

* 100 Cubic inches of pure water deprived of its air by boiling, and cooled without contact with air, absorb at 60° Fahrenheit, and 30ll Barometer, 6.5 cubic inches of oxygen, according to Saussure, and 3.7 according to Dalton and Henry. The latter estimate is regarded as the more correct.

† Davy regarded water as composed of two proportions or equivalents of hydrogen and one of oxygen. Taking this view, and estimating the combining proportion of hydrogen at 1, the number representing the proportion in which oxygen combines, is now found to be 16, or more correctly, according to the experiments of Dulong and Berzelius, 16.018. This view of the composition of water is not generally adopted in this country, water being with us regarded as composed of single equivalents of its elements; hence, if hydrogen be assumed as 1, oxygen must be estimated at 8. For a similar reason, the numbers assigned in the text to chlorine and azote are generally reduced one-half.

‡ Perhaps the easiest way of preparing pure oxygen is to heat chlorate of potash in a tube or retort of hard glass.

§ The other elementary bodies that belong to this group are iodine, bromine, and fluorine, (see note, page 20).

IODINE.—This substance exists in a state of combination in sea water, sea

3. HYDROGEN, or inflammable air, is the lightest known substance; its specific gravity is to that of air as 732 to 10,000 [specific gravity .0722.—S]. It burns by the action of an inflamed taper, when in contact with the atmosphere. The proportion in which it combines is represented by unity, or 1. It is procured by the action of diluted oil of vitriol, or hydro-sulphuric* acid on filings of zinc or iron. It is the substance employed for filling air balloons.

4. AZOTE is a gaseous substance not capable of being condensed by any known degree of cold: its specific gravity is to that of common air as 9,516 to 10,000 [specific gravity .9722.—S]. It does not enter into combustion under common circumstances, but may be made to unite with oxygen by the agency of electrical fire. It forms nearly four-fifths of the air of the atmosphere; and may be procured by burning phosphorus in a confined portion of air. The number representing the proportion in which it combines is 26 [equivalent 14.15.—S].

5. CARBON is considered as the pure matter of charcoal, and it may be procured by passing spirits of wine through a tube heated red. It has not yet been fused; but rises in vapour at an intense heat. Its specific gravity cannot be easily ascertained; but that of the diamond, which cannot chemically be distinguished from pure carbon, is to that of water as 3,500 to 1,000. Charcoal has the remarkable property of absorbing several times its volume of different elastic fluids, which are capable of being expelled from it by heat [see note on charcoal as a manure.—S]. The number representing it is 11.4 [equivalent 6.12.—S].

6. SULPHUR is the pure substance so well known by that name: its specific gravity is to that of water as 1,990 to 1,000. It fuses at about 220° Fahrenheit; and at between 500° and 600° takes fire, if in contact

weed, and other marine and litoral bodies. It is prepared from *kelp* (the fused ashes of sea-weed). At common temperatures it is a dark bluish, or greenish-black solid, with metallic lustre. It fuses at 225° F. and boils at 347° F. rising in vapour, which has a beautiful violet colour. Its specific gravity is 3.0844 (Thomson) and its equivalent or combining proportion 126.3. In its general relations it resembles chlorine. It acts energetically on many of the metals. It combines with hydrogen forming hydriodic acid. It is used in medicine.

BROMINE.—This element also is contained in small quantity in sea water and various marine productions. It is generally prepared from *bittern*, the uncrystallisable liquor left in the process of separating common salt from sea water. At ordinary temperatures it is a liquid of a deep reddish-brown colour, emitting a strong and very disagreeable odour. It boils at 116.5°, and even at common temperatures rises in vapour resembling the fumes of nitrous acid. Its specific gravity is 3.? and its combining proportion 78.4. In all its chemical relations it is intermediate between chlorine and Iodine.

FLUORINE.—This substance has only recently been prepared; indeed no process is yet known by which it can be got free from certain other bodies. At common temperatures it is a gas of a yellowish-brown colour. It does not act on glass as was at one time supposed, but it combines readily with the metals. Its smell is said to resemble that of chlorine and burnt sugar. Its specific gravity is 1.289 and its equivalent 18.68. One of its compounds most frequently met with is fluoride of calcium or fluor spar.

* It is just possible that the students may be confused by finding the term *hydro-sulphuric acid* applied in more recent books to sulphuretted hydrogen, and not as in the text to sulphuric acid containing water. Were it necessary to apply a specific term, *hydrous* sulphuric acid, the name used by Dr. Hope, appears the least objectionable.

with the air, and burns with a pale blue flame. In this process it dissolves in the oxygen of the air, and produces a peculiar acid elastic fluid. The number representing it is 30 [equivalent 16.—S].

7. PHOSPHORUS is a solid of a pale red colour, of specific gravity 1770. It fuses at 90° [point of fusion 108°.—S], and boils at 550°. It is luminous in the air at common temperatures, and burns with great violence at 150°, so that it must be handled with great caution. The number representing it is 20.* It is procured by digesting together bone ashes and oil of vitriol, and strongly heating the fluid substance so produced with powdered charcoal.

8. BORON is a solid of a dark olive colour, infusible at any known temperature. It is a substance very lately discovered, and procured from boracic acid. It burns with brilliant sparks, when heated in oxygen, but not in chlorine. Its specific gravity, and the number representing it, are not yet accurately known [Specific gravity 2? equivalent 10.9.—S]. †

9. PLATINUM is one of the noble metals, of rather a duller white than silver, and the heaviest body in nature; its specific gravity being 21.5. It is not acted upon by any acid menstrua except such as contain chlorine: it requires an intense degree of heat for its fusion [equivalent 98.8.—S].

10. The properties of GOLD are well known. Its specific gravity is 19.277. It bears the same relation to acid menstrua as platinum: it is one of the characteristics of both these bodies, that they are very difficultly acted upon by sulphur [equivalent 199.2.—S].

11. SILVER is of specific gravity 10.4, it burns more readily than platinum or gold, which require the intense heat of electricity. It readily unites to sulphur. The number representing it is 205 [equivalent 108.—S].

12. MERCURY is the only known metal fluid at the common temperature of the atmosphere; it boils at 660°, and freezes at 39° below 0. Its specific gravity is 13.560. The number representing it is 380 [equivalent 101.—S].

13. COPPER is of specific gravity 8.890. It burns when strongly heated with red flame tinged with green. The number representing it is 120 [equivalent 31.6.—S].

* Some doubts exist as to the composition of phosphoric acid. The common opinion is, that it consists of two equivalents of phosphorus, and five of oxygen; in that case the equivalent of phosphorus is 15.7. But it appears that the evidence preponderates in favour of the view, that it consists of one of phosphorus and five of oxygen, a constitution which requires the equivalent of phosphorus to be stated at 31.4.

† To this group of simple substances belong also silicon and selenium.

SILICON.—This substance was discovered by Davy, but he obtained it in quantities so small that its nature could not be fully ascertained. He classed it with the metals under the name of silicum; but it is now generally considered a non-metallic body. It is prepared from quartz or rock crystal which consists of this element combined with oxygen. Silicon is of a deep brown colour, and completely devoid of metallic lustre. Of acids the nitro-hydrofluoric is the only one that dissolves it. With fused alkalies and alkaline carbonates it combines very readily. Its specific gravity has not been ascertained. Its equivalent is by many considered 22.5, though this depends on the view taken of the composition of silicic acid. Silicic acid occurs as a constituent of numerous common minerals and forms a large part of almost every soil.

SELENIUM.—This substance has hitherto been met with only in small quantity and associated with pyrites. It is solid at common temperatures, possesses metallic lustre, fuses at 212° and rises in yellow coloured vapour at 650°. In

14. Cobalt is of specific gravity 7 700. Its point of fusion is very high, nearly equal to that of iron. In its calcined or oxidated state, it is employed for giving a blue colour to glass [equivalent 29.5 —S].

15, Nickel is of a white colour: its specific gravity is 8 820. This metal and cobalt agree with iron, in being attractable by the magnet. The number representing nickel is 111 [equivalent 29 5.—S].

16. Iron is of specific gravity 7.700. Its other properties are well known. The number representing it is 103 [equivalent 27.—S].

17. Tin is of specific gravity 7.291; it is a very fusible metal, and burns when ignited in the air; the number representing the proportion in which it combines is 110 [equivalent 58.—S].

18. Zinc is one of the most combustible of the common metals. Its specific gravity is about 7.210. It is a brittle metal under common circumstances; but when heated may be hammered or rolled into thin leaves, and after this operation is malleable. The number representing it is 66 [equivalent 32.3.—S].

19. Lead is of specific gravity 11.352; it fuses at a temperature rather higher than tin. The number representing it is 398 [equivalent 103 6.—S].

20. Bismuth is a brittle metal of specific gravity 9.822. It is nearly as fusible as tin; when cooled slowly it crystallizes in cubes. The number representing it is 135 [equivalent 213.—S].

21. Antimony is a metal capable of being volatilized by a strong red heat. Its specific gravity is 6.800. It burns when ignited with a faint white light. The number representing it is 170 [equivalent 129.2 —S].

22. Arsenic is of a blueish white colour, of specific gravity 8 310 [specific gravity 5.8843.—S]. It may be procured by heating the powder of common white arsenic of the shops, strongly in a Florence flask with oil. The metal rises in vapour, and condenses in the neck of the flask. The number representing it is 90. *

23. Manganesum may be procured from the mineral called manganese, by intensely igniting it in a forge mixed with charcoal powder. It is a metal very difficult of fusion, and very combustible; its specific gravity is 6.850 [specific gravity 8.013.—S]. The number representing it is 177 [equivalent 27.7.—S].

24. Potassium is the lightest known metal, being only of specific gravity .850. It fuses at about 150°, and rises in vapour at a heat a little below redness. It is a highly combustible substance, takes fire when thrown upon water, burns with great brilliancy, and the product of its combustion dissolves in the water. The number representing it is 75 [equivalent 39.15.—S] It may be made by passing fused caustic vegetable alkali, the pure kali of druggists, through iron turnings strongly ignited in a gun barrel, or by the electrization of potash by a strong Voltaic battery.

25. Sodium may be made in a similar manner to potassium. Soda or the mineral alkali being substituted for the vegetable alkali. It is of specific gravity .940. It is very combustible. When thrown upon water, it swims on its surface, hisses violently, and dissolves but does not inflame. The number representing it is 88 [equivalent 23.3.]†

its general relations it resembles sulphur. Its specific gravity is 4.3 ?, and its equivalent 39 6.

* On the supposition that arsenic acid consists of one equivalent of arsenic and five of oxygen, the equivalent of arsenic is 75.4.

† The metal *lithium* belonging to this group, was discovered by Davy subse-

26. BARIUM has as yet been procured only by electrical powers and in very minute quantities, so that its properties have not been accurately examined. The number representing it appears to be 130 [equivalent 68.7.—S].

Strontium the 27th, *Calcium* the 28th, *Magnesium* the 29th, *Silicum* the 30th, *Aluminum* the 31st, *Zirconum* the 32d, *Glucinum* the 33d, and *Ittrium* the 34th of the undecompounded bodies, like barium, have either not been procured absolutely pure, or only in such minute quantities that their properties are little known; they are formed either by electrical powers, or by the agency of potassium, from the different earths whose names they bear, with the change of the termination in *um;* and the numbers representing them are believed to be 90 strontium, 40 calcium, 38 magnesium, 31 silicum, 33 aluminum, 70 zirconum, 39 glucinum, 111 ittrium.*

Of the remaining thirteen simple bodies, twelve are metals, most of which, like those just mentioned, can only be procured with very great difficulty; and the substances in general from which they are procured are very rare in nature. They are *palladium*, *rhodium*, *osmium*, *iridium*, *columbium*, *chromium*, *molybdenum*, *cerium*, *tellurium*, *tungstenum*, *titanium*, *uranium.*† The forty-seventh body has not as yet been produced in a state sufficiently pure to admit of a minute examination (see note p. 22). It is the principle which gives character to the acid called fluoric acid, and may be named *fluon*, and is probably analogous to phosphorus or sulphur. The numbers representing these last thirteen bodies have not yet been determined with sufficient accuracy to render a reference to them of any utility.

The undecompounded substances unite with each other, and the most remarkable compounds are formed by the combinations of oxygen and chlorine with inflammable bodies and metals; and these combinations usually take place with much energy, and are associated with fire.

Combustion in fact, in common cases, is the process of the solution of a body in oxygen, as happens when sulphur or charcoal is burnt; or the fixation of oxygen by the combustible body in a solid form, which takes place when most metals are burnt, or when phosphorus inflames; or the production of a fluid from both bodies, as when hydrogen and oxygen unite to form water.

When considerable quantities of oxygen or of chlorine unite to metals or inflammable bodies, they often produce acids; thus sulphureous, phosphoric, and boracic acids are formed by a union of considerable quantities of oxygen with sulphur, phosphorus, and boron: and muriatic acid gas is formed by the union of chlorine and hydrogen.

When smaller quantities of oxygen or chlorine unite with inflammable

quently to 1813. It occurs in but a few rather rare minerals. The metal itself has been but little examined. Its oxide greatly resembles potash and soda, but is distinguished by communicating a red tint to flame, by its higher neutralizing power, and by some of its salts being less soluble than the corresponding ones of these bases. Its equivalent is 6.

* Although most of these metals have been re-examined, they have been prepared in quantities so small that little additional information has been elicited.

The oxides of some of them are highly important as entering largely into the composition of soils, and will be noticed as such afterwards. The equivalents at present received are strontium 43.8, calcium 20.5, magnesium 12.7, aluminum 13.7, zirconium 33.7, glucinum 26.5, ittrium 32.2.

† The remaining four metals, cadmium, thorium, vanadium, and lantanium, have been discovered since 1813. They occur in inconsiderable quantities, and do not demand in this place more particular notice.

bodies or metals, they form substances not acid, and more or less soluble in water; and the metallic oxides, the fixed alkalies, and the earths, all bodies connected by analogies, are produced by the union of metals with oxygen.

The composition of any compounds, the nature of which is well known, may be easily learnt from the numbers representing their elements; all that is necessary, is to know how many proportions enter into union. Thus *potassa*, or the pure caustic vegetable alkali, consists of one proportion of potassium and one of oxygen, and its constitution consequently is 75 potassium, 15 oxygen.*

CARBONIC ACID is composed of two proportions of oxygen 30, and one of carbon 11.4.†

* Referring to the numbers given in the notes, potash consists of 1 equivalent of potassium 39.15, and 1 equivalent of oxygen 8=47.15. In like manner sulphuric acid consists of one equivalent of sulphur 16.1, and 3 equivalents of oxygen 3×8=24=40.1. But if we wish to unite sulphuric acid and potash, and thus form sulphate of potash, we must take them in the proportions just stated: viz. 1 equivalent of sulphuric acid 40.1, and 1 equivalent of potash 47.15=87.25, or 1 equivalent of sulphate of potash. It is obvious, therefore, that if we can but remember the number of equivalents of each element that enters into the constitution of a compound, we need not burden the memory with analyses expressed in hundred parts, and we never can be at a loss to know the quantity of such compound that will be required when we wish to employ it for any chemical purpose.

For the purpose of giving clear and concise views of complicated chemical actions, and of the composition of bodies, especially those that have a complex constitution, chemists have, for some years, adopted symbols or abbreviated modes of expression. As it is scarcely possible without these to explain several chemical actions, a knowledge of which is required by the student of agriculture, it is necessary here to give a short explanation of symbols.

Ist, The symbol used to denote any elementary body is the first letter of its latin name; as for oxygen O, for potassium (kalium) K. When it happens that the names of two or more simple bodies commence with the same letter as boron, and barium, one of them is represented by the initial letter, and the others by the initial and another leading letter of the name, thus, boron B, barium Ba, phosphorus P, lead (plumbum) Pb, platinum Pt.

2d, When no numeral is expressed a symbol indicates a single equivalent or combining proportion of the substance. In representing more than one equivalent a number is always used, either before or after the symbol. Thus O represents 8, or one equivalent of oxygen, 2O, or O_2, represents 16, or two equivalents of oxygen.

3d, To express in symbols, or chemical formulæ, the constitution of a compound body, two methods are in use. Either to write the symbols of its elements the one after the other, or to insert between them the sign of combination, plus (+). Thus water which consists of one equivalent of hydrogen combined with one of oxygen, may be expressed HO, or H+O. Sulphuric acid, which consists of one equivalent of sulphur and three equivalents of oxygen, may be expressed S+3O, or S+O_3, or SO_3. And, to take a more complicated example, sulphate of potash which consists of two compound bodies in a state of union, viz. sulphuric acid SO_3, and potash KO; we express the compound thus SO_3 +KO, or without the sign, SO_3KO.

A table of the symbols used for the simple substances will be given in the appendix.

To one not accustomed to their use, symbols may at first seem unnecessary, but to understand them is now absolutely necessary from their constant occurrence in chemical books; and but a brief experience of their great utility will render the student unwilling to wade through a complicated and verbose description for information which he can obtain by a glance at a formula.

† Of 2 equivalents oxygen 16 and 1 equivalent carbon 6.12=22.12, symbol CO_2.

Again, LIME consists of one proportion of calcium and one of oxygen, and it is composed of 40 of calcium and 15 of oxygen.[a] And *carbonate of lime*, or pure chalk, consists of one proportion of carbonic acid 41.4, and one of lime 55.[b]

WATER consists of two proportions of hydrogen 2, and one of oxygen 15; and when water unites to other bodies in definite proportions, the quantity is 17, or some multiple of 17, *i. e.* 34 or 51, or 68, &c.[c]

SODA, or the mineral alkali, contains two proportions of oxygen to one of sodium.[d]

AMMONIA, or the volatile alkali, is composed of six proportions of hydrogen and one of azote.[e]

Amongst the earths, *Silica* or the earth of flints, probably consists of two proportions of oxygen to one of silicum; and *Magnesia*, *Strontia*, *Baryta* or *Barytes*, *Alumina*, *Zircona*, *Glucina*, and *Ittria*, of one proportion of metal, and one of oxygen.

The *metallic oxides* in general consist of the metals united to from one to four proportions of oxygen; and there are, in some cases, many different oxides of the same metal; thus there are three oxides of lead; the yellow oxide, or massicot, contains two *proportions* of oxygen; the *red oxide*, or *minium*, three; and the *puce coloured oxide* four proportions.[f] Again there are *two oxides* of *copper*, the *black* and the *orange;* the black contains two proportions of oxygen, the orange one.[g]

For pursuing such experiments on the composition of bodies as are connected with agricultural chemistry, a few only of the undecompounded substances are necessary; and amongst the compounded bodies, the common acids, the alkalies, and the earths, are the most essential substances. The elements found in vegetables, as has been stated in the introductory lecture are very few. Oxygen, hydrogen, and carbon constitute the greatest part of their organized matter. Azote, phosphorus, sulphur, manganesum, iron, silicum, calcium, aluminum, and magnesium likewise, in different arrangements, enter into their composition, or are found in the

[a] 1 equivalent calcium 20.5 + 1 equivalent oxygen 8 = 1 equivalent lime 28.5, symbol CaO.

[b] Carbonate of lime consists of one equivalent of carbonic acid CO_2, and one of lime CaO. Its symbol is CO_2CaO, and its equivalent 50.62.

[c] See former notes—water unites in the proportion of 9, or some multiple 18, 27, &c.

[d] The composition of soda, potash, lime, magnesia, &c., is similar. Hence soda consists of single equivalents. Sodium (natrium), 23.3 oxygen 8=31.3, symbol NaO.

[e] Of 3 equivalents of hydrogen and 1 of nitrogen or azote, symbol NH_3, equivalent 17.15.

[f] The yellow oxide of lead is generally regarded as a protoxide, and composed of one of lead to one of oxygen; the puce coloured oxide as a binoxide and composed of one of lead to two of oxygen; while the red oxide is, in some cases at least, composed of 2 equivalents of the yellow oxide and one of the puce coloured. The symbols of these oxides, are

Yellow PbO.
Red Pb_3O_4.
Puce PbO_2.

[g] The orange coloured oxide of copper is generally considered a dinoxide *i. e.* composed of two equivalents of lead and one of oxygen, while the black oxide is held to be a compound of single equivalents. The symbols of these oxides will therefore be

Orange oxide Cu_2O.
Black do. CuO.

agents to which they are exposed; and these twelve undecompounded substances are the elements, the study of which is of the most importance to the agricultural chemist.

The doctrine of definite combinations, as will be shewn in the following lectures, will assist us in gaining just views respecting the composition of plants, and the economy of the vegetable kingdom; but the same accuracy of weight and measure, the same statical results which depend upon the uniformity of the laws that govern dead matter, cannot be expected in operations where the powers of life are concerned, and where a diversity of organs and of functions exists. The classes of definite inorganic bodies, even if we include all the crystalline arrangements of the mineral kingdom, are few, compared with the forms and substances belonging to animated nature. Life gives a peculiar character to all its productions; the power of attraction and repulsion, combination and decomposition, are subservient to it; a few elements, by the diversity of their arrangement, are made to form the most different substances; and similar substances are produced from compounds which, when superficially examined, appear entirely different. *

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* It may not be out of place here, to notice more at length the distinctions between organic, and inorganic bodies;—

Inorganic Bodies.—1st, The number of elementary substances found in them is great. In the mineral kingdom, the whole of the fifty-five simple substances have been met with.

2d, The composition of inorganic bodies is generally less complex, than that of organic ones. Thus lime-stone, referred to in the text, consists of single equivalents of carbonic acid, and lime. Quartz, of silicic acid. Felspar, a mineral entering into the composition of many rocks, and like quartz, a constituent of most soils, consists of silicic acid, alumina, and potash, (Berthier) and these are united according to Thomson as three equivalents of tersilicate of alumina, with one equivalent of tersilicate of potash.

3d, They are not liable to spontaneous decomposition. It is true that rocks and minerals, by the continued action of heat and cold, air, water, and the substances it holds in solution, suffer disintegration and decomposition. Their *debris* forms soil, and the finer parts are slowly removed from higher, to lower levels; but this action is slow, and inconspicuous, and altogether dependent on agents external to the minerals themselves.

4th, Many of them are capable of being formed artificially. With the simpler mineral species so readily may this be effected, that chemistry has not unfrequently anticipated mineralogy, substances having been formed in the laboratory, and similar ones subsequently discovered in nature. In the case of the more complex minerals, though the difficulty is greater, it cannot be doubted, that were there motives sufficiently strong to induce chemists to great exertion, many of them could also be formed by art.

5th, They are not readily decomposed by being heated to redness. A few metallic oxides are reduced, as those of gold, mercury, &c.; some minerals that contain water lose the whole, or a portion of it, and others that contain volatile constituents are decomposed. Lime-stone for example, loses its carbonic acid, and becomes quick lime; but these cases are not common.

Organic Substances, are characterised by being formed under the influence of the vital principle, and possess properties the reverse of those just enumerated.

1st, They contain but few elements. However numerous their forms, chemical analysis shows that they all consist principally of carbon, hydrogen,

and oxygen. Nitrogen, in small quantity also exists in all plants, and in larger quantities in all animal bodies.

These four elementary principles, therefore, may be regarded as organic elements. But there occur also in all plants and animals very minute quantities of inorganic elements. These as enumerated in the text are phosphorus, sulphur, manganese, iron, silicon, calcium, magnesium, and aluminum, to which may be added potassium, and sodium, with smaller quantities—mere traces—of some others. That some of these inorganic bodies, though occurring in small quantity, perform most important functions, and are objects of the greatest importance in agriculture, will appear in the subsequent parts of the work.

2d, Their constitution is often highly complex. As the composition of many substances of vegetable origin will be noticed in the third lecture, a few instances will suffice for present illustration. Sugar for example consists of 12 equivalents of carbon, 11 of hydrogen, and 11 of oxygen, and may be represented by the formula C_{12} H_{11} O_{11}. Alcohol is represented thus C_4 H_6 O_2. Tannic acid C_{18} H_9 O_{12}. Quina C_{20} H_{12} N O_2. These formulæ represent the number, and proportion, of ultimate elements contained by the bodies, but not the manner in which they are combined. Recent researches show that similar laws regulate the combination of organic and inorganic bodies, and the student who is desirous of becoming acquainted with this interesting subject, is referred to the numerous papers on organic chemistry, that have lately appeared in the scientific periodicals, and particularly to professor Liebig's chemistry of the compound radicals, in course of publication.

3d, Organic bodies are characterized by the facility with which they undergo spontaneous decomposition. The elements of which they are composed, the carbon, hydrogen, oxygen, and nitrogen, possess a very extensive range of affinities, and are capable of uniting with one another in so many different ways, that disturbing causes, of a very slight kind, are sufficient to induce decomposition. Carbonic acid and water, are substances constantly evolved, when decomposing organic bodies are freely supplied with air. Nitrogen, again, is capable of uniting with hydrogen to produce ammonia—a substance evolved during the decomposition of animal bodies, and of such vegetables as contain it. In a similar manner, it might be shown, were it necessary, that, under other circumstances, other substances are produced, and decomposition ensured.

4th, Organic bodies are incapable of being formed artificially. We cannot form woody tissue, or cellular tissue, or oil, or fat, or starch, by taking the elements of which they are formed and causing them to combine. Certain substances derived by particular processes from organized bodies, may be made to pass into others, also found in, or capable of being derived from, organic bodies, but, in this case, the process begins with something already organized. Sugar is found in the sugar cane, the carrot, beet-root, &c., and sugar may be prepared in the laboratory, by treating wood or starch, paper or rags, with a diluted acid. Prussic acid exists in the water distilled from certain flowers and fruits, and it may be prepared by distilling yellow prussiate of potash, water, and sulphuric acid. Oxalic acid exists in the wood-sorrel, and other plants, and it may also be obtained by treating sugar with nitric acid. It will be remarked, however, that in all these cases, we merely decompose or modify some substance of organic origin, we do not reconstruct it from its elements, as we could do limestone, or gypsum.

5th, All organic bodies are decomposed by exposure to a red heat. It was shewn that in consequence of the extensive range of affinities, possessed by the organic elements, they are liable to spontaneous decomposition, and if so, it is obvious that at a red heat decomposition is certain, though the products are different.

LECTURE III.

ON THE ORGANIZATION OF PLANTS—OF THE ROOTS, TRUNK, AND BRANCHES—OF THEIR STRUCTURE—OF THE EPIDERMIS—OF THE CORTICAL AND ALBURNOUS PARTS OF LEAVES, FLOWERS, AND SEEDS—OF THE CHEMICAL CONSTITUTION OF THE ORGANS OF PLANTS, AND THE SUBSTANCES FOUND IN THEM—OF MUCILAGINOUS, SACCHARINE, EXTRACTIVE, RESINOUS, AND OILY SUBSTANCES, AND OTHER VEGETABLE COMPOUNDS, THEIR ARRANGEMENTS IN THE ORGANS OF PLANTS, THEIR COMPOSITION, CHANGES, AND USES,

VARIETY characterises the vegetable kingdom, yet there is an analogy between the forms and the functions of all the different classes of plants, and on this analogy the scientific principles relating to their organization depend.

Vegetables are living structures distinguished from animals by exhibiting no signs of perception, or of voluntary motion; and their organs are either organs of nourishment or of reproduction; organs for the preservation and increase of the individual, or for the multiplication of the species.

In the living vegetable system there are to be considered, the exterior form, and the interior constitution.

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

The *root* is that part of the vegetable which least impresses the eye; but it is absolutely necessary. It attaches the plant to the surface, is its organ of nourishment, and the apparatus by which it imbibes food from the soil. The roots of plants, in their anatomical division, are very similar to the trunk and branches.* The root may indeed be said to be a continuation of the trunk terminating in minute ramifications and filaments, and not in leaves; and by burying the branches of certain trees in the soil, and elevating the roots in the atmosphere, there is, as it were, an inversion of the functions, the roots produce buds and leaves, and the branches shoot

* In exogenous plants, the root is structurally different from the stem; for it wants both the pith, and the spiral vessels that surround it. In endogens, however, spiral vessels occur in the roots. The irregularity of ramification, the absence of stomata, of buds, and of all foliacious expansions, may also be noticed as distinctive of roots. The apex of a rootlet by which liquids are absorbed, consists of lax cellular tissue. It is termed the *spongiole.*

The functions of roots are—to fix the plant in the soil—to absorb through the spongioles, that portion of nourishment which is derived from the soil—and to excrete or throw out of the system waste matter, and bodies incapable of assimilation.

out into radical fibres and tubes. This experiment was made by Woodward on the willow, and has been repeated by a number of physiologists.

When the branch or the root of a tree is cut transversely, it usually exhibits three distinct bodies: the bark, the wood, and the pith; and these again are individually susceptible of a new division. *

The bark, when perfectly formed, is covered by a thin cuticle or *epidermis*, which may be easily separated. It is generally composed of a number of laminæ or scales, which in old trees are usually in a loose and decaying state. The epidermis is not vascular, † and it merely defends the interior parts from injury. In forest trees, and in the larger shrubs, the bodies of which are firm, and of strong texture, it is a part of little importance; but in the reeds, grasses, canes, and the plants having hollow stalks, it is of great use and is exceedingly strong, and in the microscope seems composed of a kind of glassy net-work, which is principally siliceous earth.

This is the case in wheat, in the oat, in different species of equisetum, and above all, in the rattan, the epidermis of which contains a sufficient quantity of flint to give light when struck by steel; or two pieces rubbed together produce sparks. This fact first occurred to me in 1798, and it led to experiments, by which I ascertained that siliceous earth existed generally in the epidermis of the hollow plants.

The siliceous epidermis serves as a support, protects the bark from the action of insects, and seems to perform a part in the economy of these feeble vegetable tribes, similar to that performed in the animal kingdom by the shell of the crustaceous insects. ‡

Immediately beneath the epidermis is the *parenchyma*. It is a soft substance consisting of cells filled with fluid, having almost always a greenish tint. The cells in the parenchymatous part, when examined by the microscope, appear hexagonal. This form, indeed, is that usually affected by the cellular membranes in vegetables, and it seems to be the

* This division into pith, wood, and bark, occurs only in exogenous plants. Plants are divided by Botanists into *vascular*, or flowering plants, and *cellular*, or flowerless plants. The former are more highly organized than the latter, and possess tubes or vessels of an elongated form for the transmission of fluids. In cellular plants, vessels occur only in small quantity in the higher groups, and the sap is contained and circulated in cells, or cellular tissue. Vascular plants are divided into *exogens* and *endogens*, and these are distinguishable by numerous well marked characters. The stems of exogens are divisible into a central cellular system or pith, an external cellular system or bark, and these are connected by plates of cellular tissue termed medullary rays. The wood forms a series of wedges, each of which is bounded internally by the pith, externally by the bark, and laterally by the medullary rays. Every year a new ring of wood is formed on the exterior of the former years. The leaves of exogens are reticulated, the flowers have a quinary division of parts, and the cotyledons or seed lobes, are two or more in number, and placed opposite. In the stems of *endogens*, again, there is no separation of the cellular and vascular systems—no distinction into pith, wood, and bark—no medullary rays; but the cellular and vascular systems are mixed up together, only the wood is laxer at the centre, and more condensed at the circumference of the stem. The leaves of endogens are not reticulated, but the veins run parallel to the mid-rib. The flowers have a ternary division, and the cotyledon is single, or if there are two, they are alternate in position.

† The cuticle is believed to be formed of condensed cellular tissue.

‡ This siliceous deposit is chiefly met with in endogenous plants, as grasses, canes, &c. In some of the *cellulares*, lichens particularly, where the woody tissue, which gives strength and elasticity to the higher plants is totally awanting, oxalate of lime occurs in the tissue, and appears to discharge this function.

result of the general re-action of the solid parts, similar to that which takes place in the honeycomb. This arrangement, which has usually been ascribed to the skill and artifice of the bee, seems, as Dr. Wollaston has observed, to be merely the result of the mechanical laws which influence the pressure of cylinders composed of soft materials, the nests of solitary bees being uniformly circular.

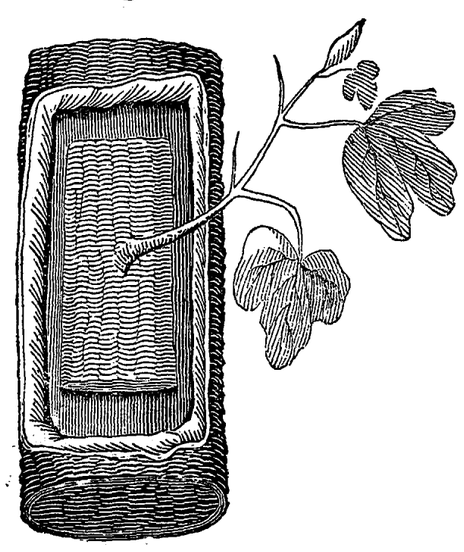
The innermost part of the bark is constituted by the *cortical layers*, and their numbers vary with the age of the tree. On cutting the bark of a tree of several years standing, the productions of different periods may be distinctly seen, though the layer of every particular year can seldom be accurately defined. *

The cortical layers are composed of fibrous parts which appear interwoven, and which are transverse and logitudinal. The transverse are membranous and porous, and the longitudinal are generally composed of tubes.

The functions of the parenchymatous and cortical parts of the bark are of great importance. The tubes of the fibrous parts appear to be the organs that receive the sap; the cells seem destined for the elaboration of its parts, and for the exposure of them to the action of the atmosphere, and the new matter is annually produced in the spring, immediately on the inner surface of the cortical layer of the last year.†

It has been shewn by the experiments of Mr. Knight, and those made by other physiologists, that the sap descending through the bark after being modified in the leaves, is the principal cause of the growth of the tree; thus if the bark is wounded, the principal formation of new bark is on the upper edge of the wound; and when the wood has been removed, the formation of new wood takes place immediately beneath the bark: yet it would appear from the late observations of M. Palisot de Beauvois, that the sap may be transferred to the bark, so as to exert its nutritive functions, independent of any general system of circulation. That gentleman separated different portions of bark from the rest of the bark in several trees, and found that in most instances the separated bark grew in the same manner as the bark in its natural state. The experiment was tried with most success on the lime-tree, the maple, and the lilac; the layers of bark were removed in August 1810, and in the spring of the next year, in the case of the maple and the lilac, small annual shoots were produced in the parts where the bark was insulated.‡

Fig. 3.



* The bark of exogens is truly endogenous. The layer of each year is cellular exteriorly and vascular interiorly. The fibrous character of the *liber* or inner bark is well seen in the *lace-bark* tree, and in the common garden mats, which are manufactured from the linden tree. It is chiefly in consequence of the exfoliation that takes place in old trees, that the age of an exogen cannot be determined by its bark, as it can by the rings of wood.

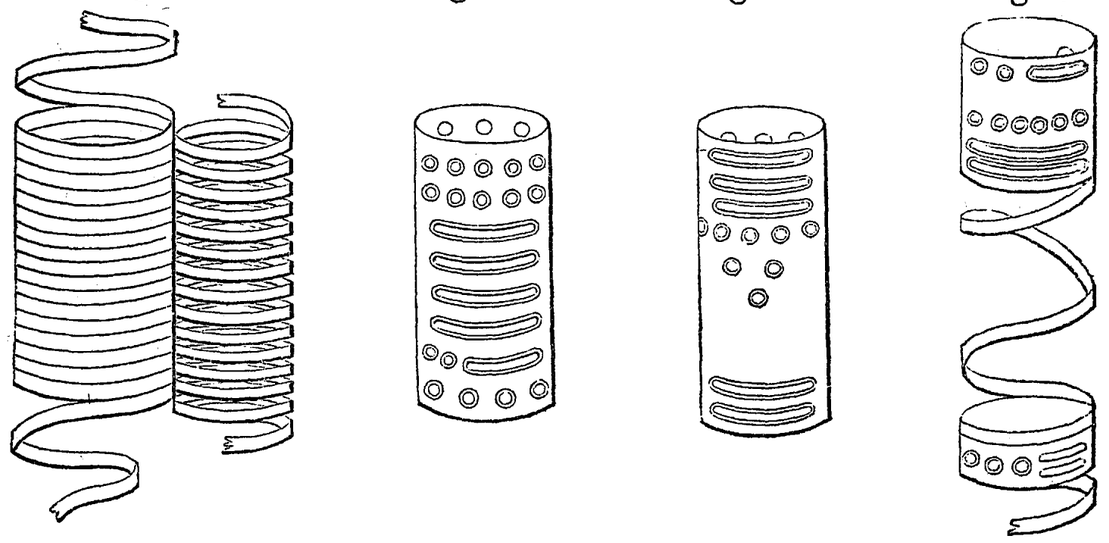
† The *cambium* is secreted between the wood and the bark. It is at first a soft viscid layer, but appears to become cellular. The wood and liber are generally believed to originate in the leaves, and to be sent down through the cambium, from the first in two independent sets of vessels.

‡ Fig. 3 represents the result of the experiment on the maple. Journal de Physique, September 1811, page 210.—D.

The wood of trees is composed of an external or living part, called *alburnum* or *sap-wood*, and of an internal and dead part, the *heart-wood*. The alburnum is white, and full of moisture, and in young trees and annual shoots it reaches even to the pith. The alburnum is the great vascular system of the vegetable through which the sap rises, and the vessels in it extend from the leaves to the minutest filaments in the roots.

There is in the alburnum a membranous substance composed of cells, which are constantly filled with the sap of the plant, and there are in the vascular system several different kinds of tubes; Mirbel has distinguished four species, the *simple tubes*, the *porous tubes*, the *tracheæ*, and the *false tracheæ*.*

Fig. 4. Fig. 5. Fig. 6. Fig. 7.



The tubes, which he has called simple tubes, seem to contain the resinous or oily fluids peculiar to different plants.

The porous tubes likewise contain these fluids; and their use is probably that of conveying them into the sap for the production of new arrangements.

The tracheæ contain fluid matter, which is always thin, watery, and pellucid, and these organs, as well as the false tracheæ, probably carry off water from the denser juices, which are thus enabled to consolidate for the production of new wood.†

* Fig. 4 represents tracheæ or spiral vessels, fig. 5 and 6 ducts. Fig. 7, at top and bottom, represents a duct, in the middle, a spiral vessel—the spire of a duct being incapable of unrolling. Perhaps this figure rather represents Mirbel's views of their nature, than any thing actually observed in plants.

† Since the first publication of the text, much light has been thrown on the structure and functions of vascular tissue. As the only essential difference between closed ducts and spiral vessels, is the power of unrolling possessed by the spire of the latter, it is fair to infer their identity in the young state of the duct. This view is supported by the fact lately brought forward by Lindley that "ducts, common as they are in the garden balsam when full grown, are scarcely to be found in that plant in a young state." Hence of the original spiriform vessels, some pass into ducts, while others continue spirals. Whatever, therefore, can be proved to be the function of spiral vessels may be assigned also to young ducts.

Notwithstanding the difference of opinion that exists on this subject, it seems almost proved, that the spiral vessels perform something like a respiratory function—that they contain and convey air. This view rests on the following among other observations:—1st, When seen under water they are opaque—an appearance they could not present if they contained a clear liquid.—2d, When

In the arrangement of the fibres of the wood, there are two distinct appearances. There are series of white and shining laminæ, which shoot from the centre towards the circumference, and these constitute what is called the *silver grain* of the wood.

Fig. 8.

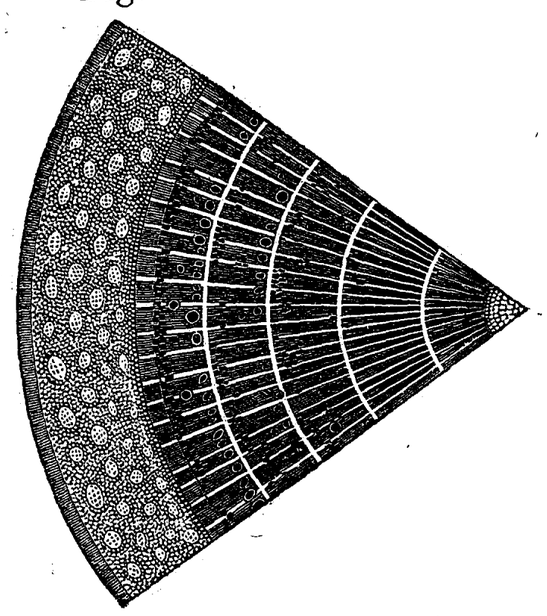


Fig. 9.

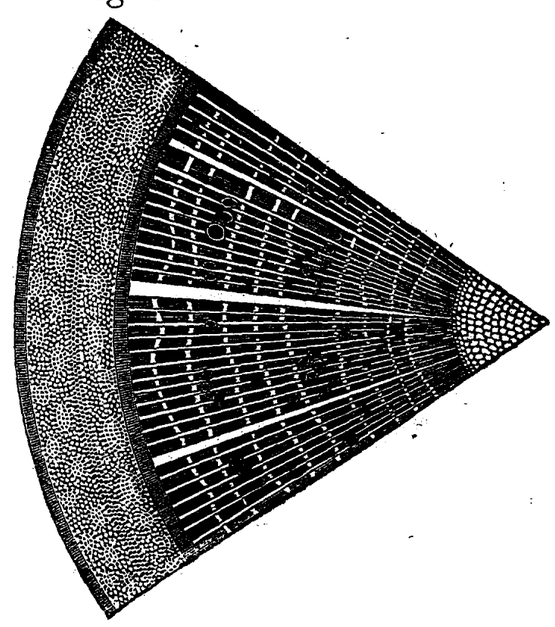
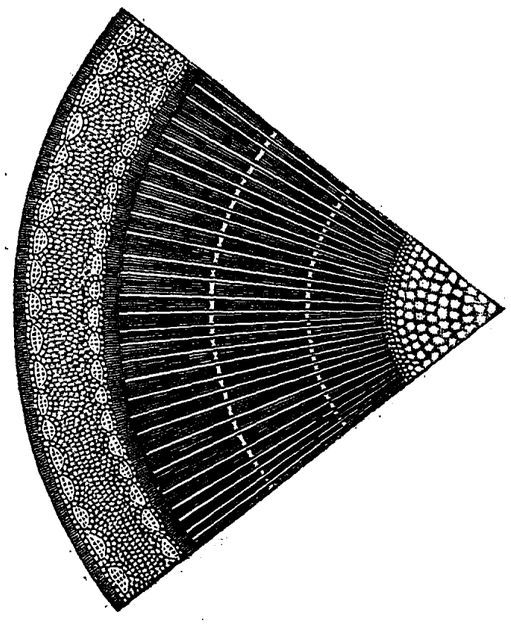


Fig. 10.



presence of spiral vessels in the roots of endogens? Why are they so equally distributed through the wood of endogens, and if they occur so abundantly in cut or wounded under water, air bubbles rise to the surface. 3d, The air that thus escapes, has been collected and analyzed by Bischoff, and found to contain from 27 to 30 per cent. of oxygen, while atmospheric air contains only 21 per cent.—4th, That spiral vessels occur in the most vital part of exogenous stems, viz. the medullary sheath.

That spiral vessels are not for the conveyance of liquids, appears from the following considerations:—1st, That no instance has been brought forward of such a vessel bleeding, when wounded.—2d, From their being in exogens, placed remote from strong sap currents, except (in the leaf-stalk for instance) where it could not be otherwise,—and 3d, From their total absence from many plants.

It ought not, however, to be forgotten, that there are still several difficulties connected with the subject, such as the following.—If they obtain air from the soil, as would appear to be the case from the circumstance that the air they contain agrees in composition with that contained in rain water, why are they absent in almost all roots of exogens? What functional difference requires the

There are likewise numerous series of concentric layers which are usually called the *spurious grain*, and their number denotes the age of the tree.*

The silver grain is elastic and contractile, and it has been supposed by Mr Knight, that the change of volume produced in it by change of temperature is one of the principal causes of the ascent of the sap. The fibres of it seem always to expand in the morning, and contract at night; and the ascent of the juices, as was stated in the last lecture, depends principally on the agency of heat.†

The silver grain is most distinct in forest trees; but even annual shrubs have a system of fibres similar to it. The analogy of nature is constant and uniform, and similar effects are usually produced by similar organs.

The *pith* occupies the centre of the wood; its texture is membranous; it is composed of cells, which are circular towards the extremity, and hexagonal in the centre of the substance. In the first infancy of the vegetable the pith occupies but a small space. It gradually dilates, and in annual shoots and young trees offers a considerable diameter. In the

the medullary sheath of exogens, might we not expect them to abound more in the outer part of the wood of endogens? The proportion of oxygen, found in the air from spiral vessels, being the same as that contained in snow water and rain water, is it not more probable that they derive it from the soil, than from carbonic acid decomposed during the circulation of the sap?—At least the nitrogen cannot be thus derived.

With respect to ducts, properly so called, there seems to be only one opinion; that they are for the transmission of liquids.

* In figures 8, 9, and 10, the white radii represent the silver grain or medullary rays of exogenous wood; the fine lines between these, the wood. The white concentric circles represent the annual layers of wood. The small circles and dots, scattered through the wood, represent vasiform tissue and ducts. On the right of the wood is represented the pith, and on the left the bark. Counting the rings of wood, it will be seen that the section of the elm branch, fig. 8, is five years old; the oak branch, fig. 9, ten years; and the ash branch, fig. 10, three years.

† This view of the cause of the circulation of the sap has been generally abandoned, both as inconsistent with the anatomical structure, and as insufficient to account for the phenomena. Indeed, the fact, that, were it true, it could apply only to exogens, is sufficient to warrant its rejection as insufficient.

At the present time, two hypotheses principally compete for public favour; viz., that of Du Petit Thouars, and that of Dutrochet. According to the former, the rise of the sap is a consequence of the expansion of buds, and the developement of leaves. As these organs grow, the juices stored up in their vicinity are appropriated, and to fill the vacant spaces thus formed, sap is forced up from below; and thus a current from the root to the growing points is established. In proof of this hypothesis, reference has been made to a well known fact, that in spring, the buds of a tree felled in winter, will expand, and the full developement of leaves is prevented, only by the want of supplies from the root.

Dutrochet's view is based partly on experiment and partly on hypothetical considerations. If on one side of a vegetable or animal membrane, is placed a fluid of greater density, and on the other a fluid of less density, it is found that both will pass through the membrane, but that an accumulation will take place on the side of the denser fluid. Farther, if the same fluid is placed on both sides of a membrane, and if the positive electrode of a voltaic battery be introduced into the fluid on one side, and the negative electrode on the other, currents will be established both ways, but an accumulation will take place on the negative side. Hence Dutrochet concludes that, in the first experiment, the denser fluid is electro-negative, and the rarer fluid electro-positive. The terms

more advanced age of the tree, acted on by the heart-wood, pressed by the new layers of the alburnum, it begins to diminish, and in very old forest trees disappears altogether.*

Many different opinions have prevailed with regard to the use of the pith. Dr. Hales supposed that it was the great cause of the expansion and developement of the other parts of the plant; that being the most interior, it was likewise the most acted upon of all the organs, and that from its reaction the phenomena of their developement and growth resulted.

Linnæus, whose lively imagination was continually employed in endeavours to discover analogies between the animal and vegetable systems, conceived "that the pith performed for the plant the same functions as the brain and nerves in animated beings." He considered it as the organ of irritability, and the seat of life.

The latest discoveries have proved, that these two opinions are equally erroneous. Mr. Knight has removed the pith in several young trees, and they continued to live and to increase.

It is evidently then only an organ of secondary importance. In early shoots, in vigorous growth, it is filled with moisture, and it is a reservoir, perhaps, of fluid nourishment at the time it is most wanted. As the heart-

exosmose and *endosmose* have been proposed by Dutrochet to express accumulation from within, and accumulation from without; and as the sap is rare when taken up by the roots, and becomes denser as it ascends, it is said to rise by endosmose.

Of these hypotheses it may be remarked, that Du Petit Thouars's does not account for the expansion of buds, and that it does not account for the return of the proper juices out of the leaf after elaboration. And this last objection is with all fairness brought against Du Petit Thouars, whose theory of the origin of wood must be very incomplete without it.

Dutrochet's hypothesis has been very extensively adopted, although few are disposed to go the length of attributing the currents to different electrical conditions of the fluids. This, however, is not essential, it being sufficient for the purpose to rest on the first experiment. In favour of Dutrochet's explanation it may be noticed,—

1st, That it is quite consistent with what is known regarding the different densities of the sap in different parts of its circuit.

2d, Membranous and closed vessels are required by this view, and such is found to be the actual texture of the tissues.

3d, It accounts for the circulation of sap in cellular plants, and in cellular portions of vascular plants, better than any other hypothesis.

It is well known that a decrease of temperature retards the flow of liquids, but it has not been shown with sufficient clearness, why, on Dutrochet's principle, a circulation, though not a vigorous one, does not take place in winter when the temperature is above freezing.

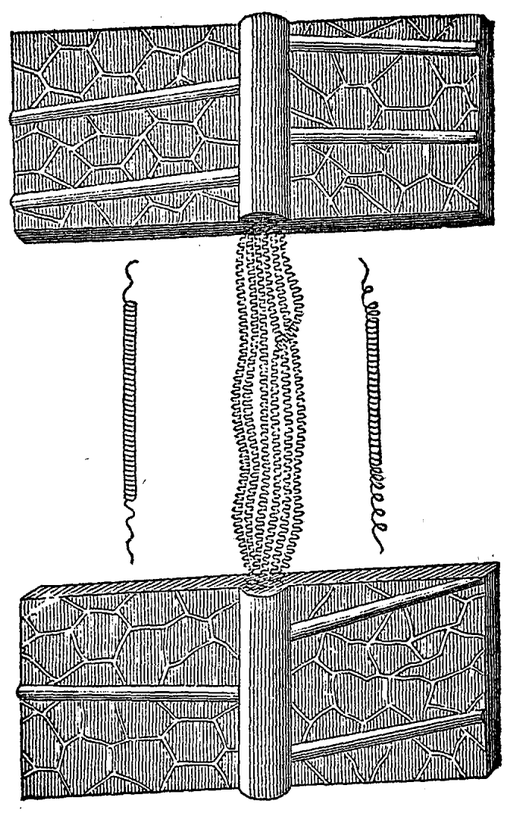
* It is true that the pith in the stems of many trees, is smaller than that in the branches, but it does not follow, that the former was at first as large and became less by compression. In young plants, the pith is originally small; but when the plant has extended its roots, and acquired a vigorous and rapid growth, the pith then formed is of considerably greater diameter. The pith in the stems of old trees, though its tissue is dry, shrivelled, and of inconsiderable size, exbibits no evidence of having suffered greater compression than that in the branches.

This opinion seems to have arisen from an error entertained regarding *duramen* or heart-wood, which is denser and harder than the sap-wood. This greater density does not arise from the pressure of the outer layers, but from the filling up of the tissues with solid matter, as may be proved by macerating a piece of heart-wood in a proper solvent, by which the solid matter is removed; the specimen will then be found to resemble sap-wood.

wood forms it is more and more separated from the living part, the alburnum; its functions become extinct, it diminishes, dies, and at last disappears.

The *tendrils*, the *spines*, and other similar parts of plants, are analogous in their organization to the branches, and offer a similar cortical and alburnous organization. It has been shown, by the late observations of Mr Knight, that the directions of tendrils, and the spiral form they assume, depend upon the unequal action of light upon them, and a similar reason has been assigned by M. Decandolle to account for the turning of the parts of plants towards the sun; that ingenious physiologist supposes that the fibres are shortened by the chemical agency of the solar rays upon them, and that, consequently, the parts will move towards the light.

Fig. 11.



The *leaves*, the great sources of the permanent beauty of vegetation, though infinitely diversified in their forms, are in all cases similar in their interior organization, and perform the same functions.

The alburnum spreads itself from the foot-stalks into the very extremity of the leaf; it retains its vascular system and its living powers; and its peculiar tubes, particularly the tracheæ, may be distinctly seen in the leaf.*

The green membranous substance may be considered as an extension of the parenchyma, and the fine and thin covering as the epidermis. Thus the organization of the roots and branches may be traced into the leaves, which present, however, a more perfect, refined, and minute structure.

One great use of the leaves is, for the exposure of the sap to the influence of the air, heat, and light. Their surface is extensive, the tubes and cells very delicate, and their texture porous and transparent.

In the leaves much of the water of the sap is evaporated; it is combined with new principles, and fitted for its organizing functions, and probably passes, in its prepared state, from the extreme tubes of the alburnum, into the ramifications of the cortical tubes, and then descends through the bark.

On the upper surface of leaves, which is exposed to the sun, the epidermis is thick but transparent, and is composed of matter possessed of little organization, which is either principally earthy, or consists of some homogeneous chemical substance. In the grasses it is partly siliceous, in the laurel resinous, and in the maple and thorn it is principally constituted by a substance analogous to wax.

By these arrangements any evaporation, except from the appropriated tubes, is prevented.

On the lower surface the epidermis is a thin transparent membrane full of cavities, and it is probably altogether by this surface that moisture and the principles of the atmosphere necessary to vegetation are absorbed.

If a leaf be turned, so as to present its lower surface to the sun, its

* Fig. 11 represents part of a leaf of a vine magnified and cut, so as to exhibit the tracheæ; it is copied, as are also the preceding figures, from Grew's Anatomy of Plants.—D.

fibres will twist so as to bring it as much as possible into its original position; and all leaves elevate themselves on the foot-stalk during their exposure to the solar light, and as it were move towards the sun.

This effect seems in a great measure dependent upon the mechanical and chemical agency of light and heat. Bonnet made artificial leaves, which, when a moist sponge was held under the lower surface, and a heated iron above the upper surface, turned exactly in the same manner as the natural leaves. This, however, can be considered only as a very rude imitation of the natural process. (see note, page 18.)

What Linnæus has called the sleep of the leaves, appears to depend wholly upon the defect of the action of light and heat, and the excess of the operation of moisture.

This singular but constant phenomenon had never been scientifically observed, till the attention of the botanist of Upsal was fortunately directed to it. He was examining particularly a species of lotus, in which four flowers had appeared during the day, and he missed two in the evening; by accurate inspection, he soon discovered that these two were hidden by the leaves which had closed round them. Such a circumstance could not be lost upon so acute an observer. He immediately took a lantern, went into his garden, and witnessed a series of curious facts before unknown. All the simple leaves of the plants he examined, had an arrangement totally different from their arrangement in the day: and the greater number of them were seen closed or folded together.

The sleep of leaves is, in some cases, capable of being produced artificially. Decandolle made this experiment on the sensitive plant By confining it in a dark place in the day time, the leaves soon closed; but on illuminating the chamber with many lamps, they again expanded. So sensible were they to the effects of light and radiant heat.

In the greater number of plants the leaves annually decay, and are reproduced; their decay takes place either at the conclusion of the summer, as in very hot climates, when they are no longer supplied with sap, in consequence of the dryness of the soil, and the evaporating powers of heat; or in the autumn, as in the northern climates, at the commencement of the frosts. The leaves preserve their functions, in common cases, no longer than there is a circulation of fluids through them. In the decay of the leaf, the colour assumed seems to depend upon the nature of the chemical change, and as acids are generally developed, it is usually either reddish brown or yellow; yet there are great varieties. Thus, in the oak it is bright brown; in the beech, orange; in the elm, yellow; in the vine, red; in the sycamore, dark brown; in the cornel tree, purple; and in the woodbine, blue.*

The cause of the preservation of the leaves of evergreens through the winter is not accurately known. From the experiments of Hales, it appears that the force of the sap is much less in plants of this species, and probably there is a certain degree of circulation throughout the winter;

* The variety in the tints of green of our finest trees has often been remarked, but the richer and more striking variety of their autumnal foliage has been less noticed, partly on account of its short duration, and partly because it is only when still and serene weather occurs in autumn, that the leaves continue to hang in sufficient numbers to afford a remarkable contrast between the tints of different species. Artists are well aware of the circumstance, and some of them have availed themselves of this knowledge in a remarkable manner.

The fall of the leaf is ascribed in the text to drought, in warm climates, and to frosts in colder ones. These causes no doubt concur with another, the filling

their juices are less watery than those of other plants, and probably less liable to be congealed by cold, and they are defended by stronger coatings from the action of the elements.

The production of the other parts of the plant takes place at the time the leaves are most vigorously performing their functions. If the leaves are stripped off from a tree in spring, it uniformly dies, and when many of the leaves of forest trees are injured by blasts, the trees always become stag-headed and unhealthy.

The leaves are necessary for the existence of the individual tree, the *flowers* for the continuance of the species. Of all the parts of plants they are the most refined, the most beautiful in their structure, and appear as the master-work of nature in the vegetable kingdom. The elegance of their tints, the variety of their forms, the delicacy of their organization, and the adaptation of their parts, are all calculated to awaken our curiosity, and excite our admiration.

In the flower there are to be observed,—1st, the calyx, or green membranous part, forming the support for the coloured floral leaves. This is vascular, and agrees with the common leaf in its texture and organization; it defends, supports, and nourishes the more perfect parts. 2d, The corolla, which consists either of a single piece, when it is called monopetalous, or of many pieces, when it is called polypetalous. It is usually very vivid in its colours, is filled with an almost infinite variety of small tubes of the porous kind; it incloses and defends the essential parts in the interior, supplies the juices of the sap to them. These parts are, 3d, the stamens and the pistils.

Fig. 12.

The essential part of the stamens are the summits or anthers, which are usually circular and of a highly vascular texture, and covered with a fine dust called the *pollen*. *

The pistil is cylindrical, and surmounted by the style; the top of which is generally round and protuberant. †

In the pistil, when it is examined by the microscope, congeries of spherical forms may usually be perceived, which seem to be the bases of the future seeds.

It is upon th arrangement of the stamens and the pistils, that the

up of the tissues with earthy and saline matter, in causing the *death* of the leaf. But its fall must be attributed to another cause, for these are applicable to all plants, and many do not shed their leaves, such as palms, grasses, and other endogens.

Du Petit Thouars' explanation is, that as the vessels which occupy the upper portion of the leaf are continuations of the medullary sheath, while the cellular tissue is a prolongation of the bark, and the returning vessels are continued into the liber, the new wood must necessarily separate these portions. Now, in consequence of the uncoiling of the spiral vessels, this separation is admitted to a certain extent, but when the spire can uncoil no farther, the connexion with the sheath is destroyed and the leaf falls.

* The anther consists of a bag composed almost entirely of cellular tissue, and contains the fine granules called pollen. The forms of anthers vary, but they are often oval, and consist of two cells with a septum or partition between them.

† Fig. 12 represents the common lily, *aa*, the corolla, *bbb*, the anthers, *c*, the pistil.—D.

Linnæan classification is founded. The numbers of the stamens and pistils in the same flower, their arrangements, or their division in different flowers, are the circumstances which guided the Swedish philosopher, and enabled him to form a system admirably adapted to assist the memory, and render botany of easy acquisition; and which, though it does not always associate together the plants most analogous to each other in their general characters, is yet so ingeniously contrived as to denote all the analogies of their most essential parts.

The pistil is the organ which contains the rudiments of the seed; but the seed is never formed as a reproductive germ, without the influence of the pollen, or dust on the anthers.

This mysterious impression is necessary to the continued succession of the different vegetable tribes. It is a feature which extends the resemblances of the different orders of beings, and establishes, on a great scale, the beautiful analogy of nature.

The ancients had observed, that different date trees bore different flowers, and that those trees producing flowers which contained pistils bore no fruit, unless in the immediate vicinity of such trees as produced flowers containing stamens. This long established fact strongly impressed the mind of Malpighi, who ascertained several analogous facts with regard to other vegetables. Grew, however, was the first person who attempted to generalize upon them, and much just reasoning on the subject may be found in his works. Linnæus gave a scientific and distinct form to that which Grew had only generally observed, and has the glory of establishing what has been called the sexual system, upon the basis of minute observations and accurate experiments.*

The seed, the last production of vigorous vegetation, is wonderfully diversified in form. Being of the highest importance to the resources of nature, it is defended above all other parts of the plant; by soft pulpy

* Since the time of Linnæus many eminent Botanists have investigated this interesting subject. It has been ascertained that the grains of pollen detained on the viscid stigma, send out *pollen tubes*, which gradually penetrate the tissue of the style and descend till they reach the ovules. That they enter the ovules through apertures in their coats, and at last penetrate the neucleus where they evacuate a fluid which is believed to become the embryo. That the embryo in its very young state is supported by nourishment laid up in the tissues of the neucleus.

Without this application of the pollen, seeds are never fertile. The ovaries may grow, the fruit may swell, and present, in some instances, all the external appearances of perfect fruit, but if the seeds are not fertilized, they cannot vegetate or produce a new plant.

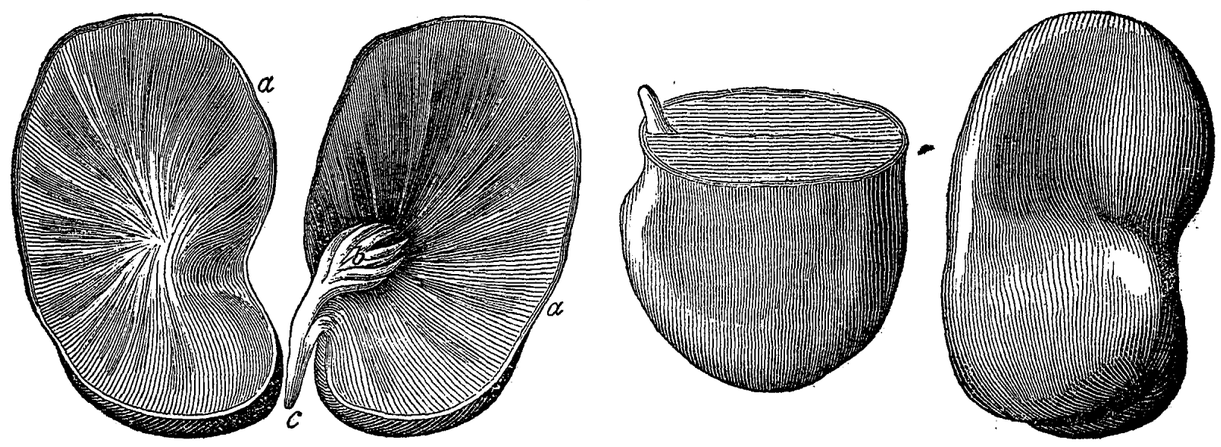
When the pollen of one species is applied to the stigma of another, fertilization does not take place, unless the species be very nearly allied; and the plant produced by such a seed is intermediate in its characters between those of its parents. It is termed a hybrid or mule. Such hybrids are rarely capable of producing fertile seeds, and when they do so they are short lived Between varieties of the same species, and particularly cultivated varieties, the facility of obtaining hybrids is greatly increased; and they produce fertile and often constant hybrids.

This power of producing permanent hybrid varieties, has been turned to excellent account by those seedsmen and agriculturists who have lately given attention to improved kinds of turnips and several other plants; and it has been amply proved that man may in this way greatly improve and fit for the peculiarities of artificial culture the plants presented to him by nature. It is to be regretted, however, that on this important subject, experiments have too often been conducted and recorded in a way anything but accurate or scientific.

substances, as in the esculent fruits, by thick membranes, as in the leguminous vegetables, and by hard shells, or a thick epidermis, as in the palms and grasses.

In every seed there is to be distinguished, 1, the organ of nourishment; 2, the nascent plant, or the plume; 3, the nascent root, or the radicle.

Fig. 13.



In the common garden bean, the organ of nourishment is divided into two lobes called cotyledons; the plume is the small white point between the upper part of the lobes; and the radicle is the small curved cone at their base.*

In wheat, and in many of the grasses, the organ of nourishment is a single part, and these plants are called *monocotyledonous*. In other cases it consists of more than two parts, when the plants are called *polycotyledonous*. In the greater number of instances, it is, however, simply divided into two, and is *dicotyledonous*.

The matter of the seed, when examined in its common state, appears dead and inert; it exhibits neither the forms nor the functions of life. But let it be acted upon by moisture, heat and air, and its organized powers are soon distinctly developed. The cotyledons expand, the membranes burst, the radicle acquires new matter, descends into the soil, and the plume rises towards the free air. By degrees, the organs of nourishment of dicotyledonous plants become vascular, and are converted into seed leaves, and the perfect plant appears above the soil. Nature has provided the elements of germination on every part of the surface; water and pure

It is important for those who have no experience in experiments of this nature to notice, that the characters of the flowers and fruit in a hybrid, resemble the plant of which the pollen was used, or the male parent, while the characters of the leaves and other parts resemble those of the plant to whose stigma the pollen was applied, namely, the female parent. Thus, for example, if of two varieties of *Oat*, one produced seed of a desirable kind, but was inferior in strength and quality of straw, while another possessing these qualities, was in some degree deficient in the first, the course of procedure would be to apply the pollen of the first, to the stigma of the second, and not the pollen of the second to the stigma of the first.

It is in the parts of fructification that the vegetable and animal systems bear the closest analogy. But it would be improper to take it for granted, that all that has been determined regarding the crossing of races in the latter will certainly follow in the former. Indeed, no more fertile source of error in vegetable physiology could be mentioned, than the assumption too frequently made, that the functions of plants and animals are exactly parallel.

* Fig. 13, represents the garden bean, *aa* the cotyledons, *b* the plume, *c* the radicle.—D

air and heat are universally active, and the means for the preservation and multiplication of life, are at once simple and grand.

To enter into more minute details on the vegetable physiology would be incompatible with the objects of these lectures. I have attempted only to give such general ideas on the subject, as may enable the philosophical agriculturist to understand the functions of plants; those who wish to study the anatomy of vegetables, as a distinct science, will find abundant materials in the works of the authors I have quoted, page 4, and likewise in the writings of Linnæus, Desfontaines, Decandolle, de Saussure, Bonnet, and Smith. *

The history of the peculiarities of structure in the different vegetable classes, rather belongs to botanical than agricultural knowledge. As I mentioned in the commencement of this Lecture, their organs are possessed of the most distinct analogies, and are governed by the same laws. In the grasses and palms, the cortical layers are larger in proportion than the other parts; but their uses seem to be the same as in forest trees. †

In bulbous roots, the alburnous substance forms the largest part of the vegetable; but in all cases it seems to contain the sap, or solid materials deposited from the sap.

The slender and comparatively dry leaves of the pine and the cedar perform the same functions as the large and juicy leaves of the fig tree, or the walnut.

Even in the cryptogamia, where no flowers are distinct, still there is every reason to believe that the production of the seed is effected in the same way as in the more perfect plants. The mosses and lichens which belong to this family, have no distinct leaves, or roots, but they are furnished with filaments which perform the same functions; and even in the fungus and the mushroom there is a system for the absorption and aeration of the sap.

It was stated in the last lecture, that all the different parts of plants are capable of being decomposed into a few elements. Their uses as food, or for the purposes of the arts, depend upon compound arrangements of those elements which are capable of being produced either from their organized parts, or from the juices they contain; and the examination of the nature of these substances, is an essential part of agricultural chemistry.

Oils are expressed from the fruits of many plants; resinous fluids exude

* It would be easy to add to this list of Botanists and Physiologists, the names of many British, and particularly Foreign authorities. The English reader will consult with the greatest advantage, the writings of Professor Lindley, particularly his "Introduction to Botany," where he will find the most accurate information on structure, together with an admirable digest of the opinions of all the leading Foreign Physiologists, on points either recently settled or still doubtful. For a short, but clear and accurate statement, Professor Henslow's small volume on "Descriptive and Physiological Botany," in the Cabinet Cyclopædia, may also be referred to, as well as the numbers on "Botany and Vegetable Physiology" in the Library of Useful Knowledge.

† In endogens there is no bark in the sense in which we speak of it in exogens. The cellular and vascular systems are intermixed, as is apparent on making a section of a cane. From the new wood being sent down the centre of the stem, the exterior parts become firm and compact, but no addition is made to them from without. Some endogens are hollow, in consequence of very rapid lateral growth. This is well seen in the grasses, but even in them the young shoot is solid at first, and were those of our climate not herbacious the stem would in time become again solid.

from the wood; saccharine matters are afforded by the sap; and dyeing materials are furnished by leaves, or the petals of flowers: but particular processes are necessary to separate the different compound vegetable substances from each other, such as maceration, infusion or digestion in water, or in spirits of wine: but the application and the nature of these processes will be better understood when the chemical nature of the substances is known; the consideration of them will therefore be reserved for another place in this lecture.

The compound substances found in vegetables are 1, gum, or mucilage, and its different modifications; 2, starch; 3, sugar; 4, albumen; 5, gluten; 6, gum elastic; 7, extract; 8, tannin; 9, indigo; 10, narcotic principle; 11, bitter principle; 12, wax; 13, resins, 14, camphor; 15, fixed oils; 16, volatile oils; 17, woody fibre; 18, acids; 19, alkalies; earths, metallic oxides, and saline compounds.

I shall describe generally the properties and composition of these bodies, and the manner in which they are procured.

1. GUM is a substance which exudes from certain trees; it appears in the form of a thick fluid, but soon hardens in the air, and becomes solid: when it is white, or yellowish white, more or less transparent, and somewhat brittle; its specific gravity varies from 1300 to 1490.

There is a great variety of gums, but the best known are gum arabic, gum senegal, gum tragacanth, and the gum of the plum or cherry tree. Gum is soluble in water, but not soluble in spirits of wine. If a solution of gum be made in water, and spirits of wine or alcohol be added to it, the gum separates in the form of white flakes. Gum can be made to inflame only with difficulty; much moisture is given off in the process, which takes place with a dark smoke and feeble blue flame, and a coal remains.

The characteristic properties of gum are its easy solubility in water, and its insolubility in alcohol.* Different chemical substances have been proposed for ascertaining the presence of gum, but there is reason to believe that few of them afford accurate results; and most of them (particularly the metallic salts), which produce changes in solutions of gum, may be conceived to act rather upon some saline compounds existing in the gum, than upon the pure vegetable principle.† Dr. Thomson has proposed an aqueous solution of silica in potassa as a test of the presence of gum in solutions—he states that the gum and silica are precipitated together—this test, however, cannot be applied with correct results in cases when acids are present.

Mucilage must be considered as a variety of gum; it agrees with it in its most important properties, but seems to have less attraction for water.—According to Hermbstadt, when gum and mucilage are dissolved together in water, the mucilage may be separated by means of sulphuric acid—mucilage may be procured from linseed, from the bulbs of the hyacinth, from the leaves of the marsh-mallows; from several of the lichens, and from many other vegetable substances.‡

* It is characterized also by producing mucic acid when boiled with nitric acid.

† Of metallic salts that which answers best is trisacetate of oxide of lead. The precipitate formed by this salt has been shown to be a definite compound of gum and oxide of lead.

‡ According to Raspail many of the varieties of gum, the analyses of which give different results from that of gum arabic, are by no means pure, but consist of gum, mixed with variable quantities of salts, woody and glutinous matters, &c.

From the analysis of MM. Gay Lussac and Thenard, it appears that gum arabic contains in 100 parts:

of Carbon	42·23
— Oxygen	50 84
— Hydrogen	6·93
with a small quantity of saline and earthy matter.	
or of Carbon	42·23
Oxygen and Hydrogen in the proportions necessary to form water	57·77

This estimation agrees very nearly with the definite proportions of 11 of carbon, 10 of oxygen, and 20 of hydrogen.*

All the varieties of gum and mucilage, are nutritious as food. They either partially or wholly lose their solubility in water by being exposed to a heat of 500° or 600° Fahrenheit, but their nutritive powers are not destroyed unless they are decomposed. Gum and mucilage are employed in some of the arts, particularly in calico-printing: till lately, in this country, the calico-printers used gum arabic; but many of them, at the suggestion of Lord Dundonald, now employ the mucilage from lichens. †

2. STARCH is procured from different vegetables, but particularly from wheat or from potatoes. To make starch from wheat, the grain is steeped in cold water till it becomes soft, and yields a milky juice by pressure; it is then put into sacks of linen, and pressed in a vat filled with water: as long as any milky juice exudes the pressure is continued; the fluid gradually becomes clear, and a white powder subsides, which is starch.

Starch is soluble in boiling water,‡ but not in cold water, nor in spirits of wine. According to Dr. Thomson, it is a characteristic property of starch to be soluble in a warm infusion of nutgalls, and to form a precipitate when the infusion cools. §

Starch is more readily combustible than gum; when thrown upon red hot iron, it burns with a kind of explosion, and scarcely any residuum

* Berzelius's analysis agrees closely with the above. The composition of gum is identical with that of cane sugar. Both may be represented by the formula C_{12} H_{11} O_{11}.

† A substance much employed by calico-printers is prepared by exposing dry starch to a temperature considerably above 212°. Thus treated, it is changed in colour, becomes readily soluble in cold water, and partakes in this respect more of the nature of gum. It is distinguished from starch, by its not giving a blue, with iodine, and from gum, by not affording mucic acid when boiled with nitric acid.

‡ Starch when acted on by boiling water becomes soluble. The solution after being evaporated and cautiously dried, affords a hard substance of a horny appearance, to which the name *amidine* is sometimes applied. This substance is soluble in cold water. A heat of 212° applied to starch, in the dry state, produces a similar change in its solubility, and the solution in cold water strikes the same blue with solution of iodine, that a solution of starch in hot water does.

It appears that each grain of starch is found in the plants that produce it enveloped in a membrane, which is destroyed by grinding, grating, heat, or the action of strong acids. This membrane protects the starch from the action of many solvents; and to these ruptured membranes, according to Raspail, are to be attributed many of the properties formerly assigned to starch. From the wax that remains after treating potato starch with nitric acid, Liebig infers that each grain consists of concentric layers of wax and *amylum*. It is obvious, therefore, that unless prepared with very great care, starch may contain several proximate principles.

§ The most distinctive character of starch is that already referred to, its striking a blue colour with solution of iodine.

remains. According to MM. Gay Lussac and Thenard, 100 parts of starch are composed of

	Carbon, with a small quantity of saline and earthy matter	43·55
	Oxygen	49·68
	Hydrogen	6·77
or,	Carbon	43·55
	Oxygen and Hydrogen in the proportions necessary to form water	56·45

Supposing this estimation correct, starch may be conceived to be constituted by 15 proportions of carbon, 13 of oxygen, and 26 of hydrogen. *

Starch forms a principal part of a number of esculent vegetable substances. Sowans, cassava, salop, sago,† all of them owe their nutritive powers principally to the starch they contain.

Starch has been found in the following plants:—

Burdock (Arctium Lappa), Deadly Nightshade (Atropa Belladonna), Bistort (Polygonum Bistorta), White Bryony (Bryonia alba), Meadow Saffron (Colchicum autumnale), Dropwort (Spiræa Filipendula), Buttercup (Ranunculus bulbosus), Figwort (Scrophularia nodosa), Dwarf Elder (Sambucus Ebulus), Common Elder (Sambucus nigra), Foolstones (Orchis Morio), Alexanders (Imperatoria Ostruthium), Henbane (Hyoscyamous niger), Broad-leaved Dock (Rumex obtusifolius), Sharp-pointed Dock (Rumex acutus), Water Dock (Rumex aquaticus), Wake Robin, (Arum maculatum), Salep (Orchis mascula), Flower de luce or Water flag (Iris Pseudacorus), Stinking Gladwyn (Iris fœtidissima), Earthnut (Bunium Bulbocastanum.)

3. SUGAR in its purest state is prepared from the expressed juice of the saccharum officinarum, or sugar cane; the acid in this juice is neutralized by lime, and the sugar is crystallized by the evaporation of the aqueous parts of the juice, and slow-cooling: it is rendered white by the gradual filtration of water through it. In the common process of manufacture, the whitening or refining of sugar is only effected in a great length of time; the water being gradually suffered to percolate through a stratum of clay above the sugar. As the colouring matter of sugar is soluble in a saturated solution of sugar, or syrup, it appears that refining may be much more rapidly and economically performed by the action of syrup on coloured sugar.‡ The sensible properties of sugar are well

* The analysis by MM. Gay Lussac and Thenard, is of starch prepared from potatoes. Potato starch has been analysed also by Berzelius, and recently numerous analyses of starch from peas, beans, maize, wheat, rice, and various roots, and unripe fruits, have been made in the laboratory of Giessen. Whatever the source of the starch the analyses agree closely. The composition of pure starch is inferred to be C_{12} H_{10} O_{10}.

Starch occurs in plants only in cellular tissue. It is very common in fleshy roots, it occurs also in pith, and in the cotyledons and albumen. In seeds it is converted into sugar during germination, oxygen, moisture, and a certain temperature being required. Starch is capable of being converted into sugar by fermentation, or by boiling with dilute sulphuric acid. As the acid is not taken up in the process, and air is not required, it follows from the known composition of the bodies, that the change consists in the starch combining with a small quantity of the elements of water.

† Also arrow-root, tapioca, and other similar substances.

‡ A French gentleman lately in this country, stated to the West India planters, that he was in possession of a very expeditious and economical method of purifying and refining sugar, which he was willing to communicate to them

known. Its specific gravity according to Fahrenheit is about 1.6. It is likewise soluble in its own weight of water at 50°; it is soluble in alcohol, but in smaller proportions.

Lavoisier concluded from his own experiments, that sugar consists in 100 parts of

28 Carbon,
8 Hydrogen,
64 Oxygen.

Dr. Thomson considers 100 parts of sugar as composed of

27·5 Carbon,
7·8 Hydrogen,
64·7 Oxygen.

According to the recent experiments of Gay Lussac and Thenard, sugar consists of

42·47 of Carbon, and
57·53 of Water or its elements.

Lavoisier's and Dr. Thomson's analyses agree very nearly with the proportions of

3 of Carbon,
4 of Oxygen,
and 8 of Hydrogen.

Gay Lussac's and Thenard's estimation gives the same elements as in gum; 11 of carbon, 10 of oxygen, 20 of hydrogen.*

It appears from the experiments of Proust, Achard, Goettling, and Parmentier, that there are many different species of sugar ready formed in the vegetable kingdom.† The sugar which most nearly resembles that of the cane is extracted from the sap of the American maple, (acer saccharinum). This sugar is used by the North American farmers, who procure it by a kind of domestic manufacture. The trunk of the tree is bored early in spring, to the depth of about two inches; a wooden spout is introduced into the hole; the juice flows for about five or six weeks. A common

for a very great pecuniary compensation. His terms were too high to be acceded to. Conversing on the subject with Sir Joseph Banks, I mentioned to him, that I thought it probable that raw sugar might be easily purified by passing syrup through it, which would dissolve the colouring matter. The same idea seems to have occurred about the same time, or before, to Edward Howard, Esq, who has since proved its efficacy experimentally, and has published an account of his process.—D.

The process now generally followed consists in dissolving in water with the addition of some lime water, and filtering to separate impurities. The colour is removed by filtration through animal charcoal. The aqueous part is removed by boiling *in vacuo*, and the hot syrup is then poured into conical moulds to crystallize, after which the uncrystallizable portion is allowed to run off, and what still remains of it is removed by a solution of pure sugar which is poured on the base of the inverted cone and allowed to percolate to the apex where it escapes.—S.

* Of the analyses in the text that by MM. Gay Lussac and Thenard is the only one that approaches to accuracy. According to Liebig's analysis, crystallized cane sugar consists of

Carbon	42 301
Hydrogen	6·384
Oxygen	51·315

which corresponds very nearly with the formula C_{12} H_{11} O_{11}.

† Sugar identical with cane sugar is found in the juice of the American maple, in beetroot, carrots, turnips, parsnips, potatoes, and other tubers. The nectar, secreted by flowers is also of this kind Cane sugar is perfectly distinct from the sugar of fruits, of which *grape* sugar may be taken as the type. 1st, The composition of these two sugars is different, grape sugar containing a greater

sized tree, that is, a tree from two to three feet in diameter, will yield about 200 pints of sap, and every 40 pints of sap afford about a pound of sugar. The sap is neutralized by lime, and deposits crystals of sugar by evaporation.

The sugar of grapes has lately been employed in France as a substitute for colonial sugar. It is procured from the juice of ripe grapes by evaporation, and the action of pot-ashes; it is less sweet than common sugar, and its taste is peculiar: it produces a sensation of cold while dissolving in the mouth; and it is probable contains a larger proportion of water or its elements. *

The roots of the beet (beta vulgaris and cicla), afford a peculiar sugar, by boiling, and the evaporation of the extract: it agrees in its general properties with the sugar of grapes, but has a slightly bitter taste.

Manna, a substance which exudes from various trees, particularly from the fraxinus ornus, a species of ash, which grows abundantly in Sicily and Calabria, may be regarded as a variety of sugar, very analogous to the sugar of grapes.† A substance analogous to manna has been extracted by Fourcroy and Vauquelin, from the juice of the common onion (allium cepa.)

Besides the crystallized and solid sugars, there appears to be a sugar which cannot be separated from water, and which exists only in a fluid form; it constitutes a principal part of molasses or treacle; and it is found in a variety of fruits:‡ it is more soluble in alcohol than solid sugar.

The simplest mode of detecting sugar is that recommended by Margraaf. The vegetable is to be boiled in a small quantity of alcohol; solid sugar, if any exist, will separate during the cooling of the solution.

Sugar has been extracted from the following vegetable substances :—

The sap of the Birch (Betula Alba), of the Sycamore (Acer Pseudoplatanus), of the Bamboo (Arundo Bambos), of the Maize (Zea mays), of the Cow Parsnip (Heracleum Sphondylium), of the Cocoa-nut tree (Cocos nucifera), of the Walnut tree (Juglans Alba), of the American Aloe (Agave mericana), of the Dulse (Fucus palmatus), of the Common Parsnip

proportion of the elements of water. 2d, Grape sugar is not so sweet to the taste as cane sugar, for a given portion of water is rendered as sweet by dissolving one part of cane sugar, as by two and a half parts of grape sugar. 3d, The effects produced by acids and alkalies on the two sugars are different. Strong sulphuric acid chars and blackens cane sugar; while it dissolves grape sugar, only changing its colour slightly. When cane sugar is boiled in dilute alkaline solutions, the colour of the solution is not changed; grape sugar similarly treated is converted into a dark brown or black substance.

* This sugar occurs in the grape and other fruits. Honey consists chiefly of it—at least honey separated from the wax by the aid of hot water. It is this sugar that is obtained by treating cane sugar, starch, or woody tissue, with sulphuric acid and water. It is also produced by the action of a solution of malt on farinaceous substances.

The composition of grape sugar has been ascertained by many analyses. Its formula is C_{12} H_{14} O_{1}.

† Manna consists principally of *mannite* a substance whose formula is C_6 H_7 O_6. It is distinguished from sugar, among other properties, by its solutions not undergoing fermentation when treated with yeast. Mannite occurs in the juices of various trees, and is a product of the fermentation of the juice of fleshy roots, as the carrot, turnip, beet, onion, &c.

‡ It is believed that the sugar contained by fruits whose juice also contains acid is grape sugar; that it unites with the acids present, and the compounds thus formed are quite incapable of crystallization. Alkalies may be added, but they do not remove the acids. Hence it is impossible to obtain sugar from such fruits. These juices, however, are still capable of fermentation. Molasses

(Pastinica sativa), of St John's Bread (Ceratonia Siliqua); the fruit of the Common Arbutus (Arbutus Unedo), and other sweet-tasted fruits; the roots of the Turnip (Brassica Rapa), of the Carrot (Daucus Carota), of Parsley (Apium petroselinum), the flower of the Euxine Rhododendron (Rhododendron ponticum), and from the nectarium of most other flowers.

The nutritive properties of sugar are well known. Since the British market has been overstocked with this article from the West India Islands, proposals have been made for applying it as the food of cattle; experiments have been made which prove that they may be fattened by it; but difficulties connected with the duties laid on sugar, have hitherto prevented the plan from being tried to any extent.

4. ALBUMEN is a substance which has only lately been discovered in the vegetable kingdom. It abounds in the juice of the papaw tree (Carica papaya): when this juice is boiled the albumen falls down in a coagulated state. It is likewise found in mushrooms, and in different species of funguses.

Albumen in its pure form, is a thick, glairy, tasteless fluid; precisely the same as the white of egg; it is soluble in cold water: its solution, when not too much diluted, is coagulated by boiling, and the albumen separates in the form of thin flakes. Albumen is likewise coagulated by acids and by alcohol· a solution of albumen gives a precipitate when mixed with a cold solution of nut-galls. Albumen when burnt produces a smell of volatile alkali, and affords carbonic acid and water; it is therefore evidently principally composed of carbon, hydrogen, oxygen, and azote.

According to the experiments of Gay Lussac and Thenard, 100 parts of albumen from the white of the egg are composed of

Carbon	52 883
Oxygen	23 872
Hydrogen	7 540
Azote	15 705

This estimation would authorise the supposition, that albumen is composed of 2 proportions of azote, 5 oxygen, 9 carbon, 22 hydrogen *

contains a quantity of sugar mixed with large quantities of various compounds produced by the action of alkalies on sugar.

* Liebig in his recent work on animal chemistry, gives several analyses of vegetable albumen prepared from various sources. That from wheat may be taken as an example:—

Carbon	55·01
Hydrogen	7·23
Nitrogen	15·92
Oxygen, Sulphur, Phosphorus	21·84

Many analyses of animal albumen are also given; that of Mulder is as follows:—

Carbon	54·84
Hydrogen	7·09
Nitrogen	15 83
Oxygen	21·23
Sulphur	·68
Phosphorus	.33

Animal and vegetable albumen, are not merely proved to be identical in composition, but other two principles, namely, *fibrine* and *caseine*, occurring both in the animal and vegetable kingdoms, are shewn to be identical with albumen and with one another. Abstracting from the sulphur and phosphorus, these principles may be represented by the formula C_{48} N_6 H_{36} O_{14}. The only difference in composition between these principles is in the relative proportions of sulphur

The principal part of the almond, and of the kernels of many other nuts, appears, from the experiments of Proust, to be a substance analogous to coagulated albumen.

The juice of the fruit of the Ochra (Hibiscus esculentus), according to Dr. Clarke, contains a liquid albumen in such quantities, that it is employed in Dominica, as a substitute for the white of eggs, in clarifying the juice of the sugar cane.*

Albumen may be distinguished from other substances by its property of coagulating by the action of heat or acids, when dissolved in water. According to Dr. Bostock, when the solution contains only one grain of albumen to 1000 grains of water, it becomes cloudy by being heated.†

Albumen is a substance common to the animal as well as to the vegetable kingdom, and much more abundant in the former.

5. GLUTEN may be obtained from wheaten flour by the following process: the flour is to be made into a paste, which is to be cautiously washed, by kneading it under a small stream of water, till the water has carried off from it all the starch; what remains is gluten. It is a tenacious, ductile, elastic substance. It has no taste. By exposure to air it becomes of a brown colour. It is very slightly soluble in cold water, but not soluble in alcohol. When a solution of it in water is heated, the gluten separates in the form of yellow flakes; in this respect it agrees with albumen, but differs from it in being infinitely less soluble in water. The solution of albumen does not coagulate when it contains much less than 1000 parts of albumen; but it appears that gluten requires more than 1000 parts of cold water for its solution.

Gluten when burnt affords similar products to albumen, and probably differs very little from it in composition. Gluten is found in a great number of plants. Proust discovered it in acorns, chesnuts, horse-chesnuts, apples, and quinces; barley, rye, pease, and beans; likewise in the leaves of rue, cabbage, cresses, hemlock, borage, saffron, in the berries of the elder, and in the grape. Gluten appears to be one of the most nutritive of the vegetable substances; and wheat seems to owe its superiority to other grain, from the circumstance of its containing it in larger quantities.‡

6. GUM ELASTIC, or CAOUTCHOUC, is procured from the juice of a tree which grows in the Brazils, called Hævea. When the tree is punctured,

and phosphorus as exhibited in the following table deduced from Mulder's analyses.

	Albumen	Fibrine	Caseine
Sulphur	·68	·33	·36
Phosphorus	·33	·36	·00

* Albumen occurs in the juices of many, perhaps of all plants. It may be readily obtained from vegetables, such as cabbages, beetroot, turnips, &c., by exposing the expressed juices to a boiling temperature by which the albumen is coagulated.

† Albumen, like fibrine and caseine, when treated with strong muriatic acid dissolves, and the solution has a dark purple colour. The most delicate tests for albumen in solution, are corrosive sublimate and yellow prussiate of potash.

‡ The substance referred to in the text as gluten derived from wheat flour, consists according to Liebig, of fibrine and true gluten. That described as derived from other sources no doubt also contains fibrine and perhaps albumen. When the starch is washed away from wheat flour by water, and the adhesive substance which remains is treated with boiling alcohol, a small portion of it is

a milky juice exudes from it, which gradually deposits a solid substance, and this is gum elastic.

Gum elastic is pliable and soft like leather, and becomes softer when heated. In its pure state it is white; its specific gravity is ·9335. It is combustible, and burns with a white flame, throwing off a dense smoke, with a very disagreeable smell. It is insoluble in water, and in alcohol; it is soluble in ether, volatile oils, and in petroleum, and may be procured from ether in an unaltered state, by evaporating its solution in that liquid.* Gum elastic seems to exist in a great variety of plants: amongst them are *Jatropha elastica*, *Ficus indica*, *Artocarpus integrifolia*, and *Urceola elastica*.

Bird-lime, a substance which may be procured from the holly, is very analogous to gum elastic in its properties. Species of gum elastic may be obtained from the misletoe, from gum-mastic, opium, and from the berries of the *Smilax caduca*, in which last plant it has been lately discovered by Dr. Barton.

Gum elastic, when distilled, affords volatile alkali, water, hydrogen, and carbon, in different combinations. It, therefore, consists principally of azote, hydrogen, oxygen, and carbon; but the proportions in which they have combined have not yet been ascertained. Gum elastic is an indigestible substance, not fitted for the food of animals; its uses in the arts are well known.

7. EXTRACT, OR THE EXTRACTIVE PRINCIPLE, exists in almost all plants. It may be procured in a state of tolerable purity from saffron, by merely infusing it in water, and evaporating the solution. It may likewise be obtained from catechu, or *Terra japonica*, a substance brought from India. This substance consists principally of astringent matter and extract; by the action of water upon it, the astringent matter is first dissolved, and may be separated from the extract. Extract is always more or less coloured; it is soluble in alcohol and water, but not soluble in ether. It unites with alumina when that earth is boiled in a solution of extract; and it is precipitated by the salts of alumina, and by many metallic solutions, particularly the solution of muriate of tin.

From the products of its distillation, it seems to be composed principally of hydrogen, oxygen, carbon, and a little azote.

There appears to be almost as many varieties of extract as there are species of plants. The difference of their properties probably in many cases depends upon their being combined with small quantities of other vegetable principles, or to their containing different saline, alkaline, acid, or earthy ingredients.† Many dyeing substances seem to be of the nature

dissolved; this portion consists of pure gluten. Jones analyzed it in Liebig's laboratory and found it to consist in 100 parts of

Carbon	55·22
Hydrogen	7·42
Nitrogen	15·98
Oxygen &c.	21·38

shewing a composition not sensibly different from the three principles before mentioned. The portion left undissolved by the hot alcohol is fibrine, the composition of which has been already noticed.

* In ether it is difficultly soluble, and the volatile oils, such as oil of turpentine, do not, on evaporation, leave it in an unaltered state. Its best solvents are coal tar, naphtha, and *caouchoucine*, the volatile liquid, obtained from itself by careful distillation. It is the former of these substances that is employed as a solvent, in preparing the various waterproof fabrics now so common.

† The term extract is scarcely applicable to any single proximate principle, for the property of being soluble in water and alcohol belongs to so many, that it is

of extractive principle, such as the red colouring matter of madder, and the yellow dye procured from weld.

Extract has a strong attraction for the fibres of cotton or linen, and combines with these substances when they are boiled in a solution of it. The combination is made stronger by the intervention of mordants, which are earthy or metallic combinations that unite to the cloth, and enable the colouring matter to adhere more strongly to its fibres.

Extract, in its pure form, cannot be used as an article of food, but it is probably nutritive when united to starch, mucilage, or sugar.

8. TANNIN, or the tanning principle, may be procured by the action of a small quantity of cold water on bruised grape-seeds, or pounded gall-nuts; and by the evaporation of the solution to dryness.* It appears as a yellow substance, possessed of a highly astringent taste. It is difficult of combustion. It is very soluble both in water and alcohol, but insoluble in ether. When a solution of glue, or isinglass (gelatine), is mixed with an aqueous solution of tannin, the two substances, *i.e.* the animal and vegetable matters, fall down in combination, and form an insoluble precipitate.

When tannin is distilled in close vessels, the principal products are charcoal, carbonic acid, and inflammable gases, with a minute quantity of volatile alkali. Hence its elements seem the same as those of extract, but probably in different proportions. The characteristic property of tannin is its action upon solutions of isinglass or jelly; this particularly distinguishes it from extract, with which it agrees in most other chemical qualities.†

There are many varieties of tannin, which probably owe the difference of their properties to combinations with other principles, especially extract, from which it is not easy to free tannin. The purest species of tannin is that obtained from the seeds of the grape; this forms a white precipitate, with solution of isinglass. The tannin from gall-nuts resembles it in its properties. That from sumach affords a yellow precipitate; that from kino a rose coloured, that from catechu a fawn coloured one. The colouring matter of Brazil wood, which M. Chevreul considers as a peculiar principle, and which he has called *Hematine*, differs from other species of tannin, in affording a precipitate with gelatine, which is soluble in abundance of hot water. Its taste is much sweeter than that of the other varieties of tannin, and it may perhaps be regarded as a substance intermediate between tannin and extract.

Tannin is not a nutritive substance, but is of great importance in its application to the art of tanning. Skin consists almost entirely of jelly or

not distinctive. Extractive matter, therefore, means a mixture of all the proximate principles soluble in water, and alcohol, which a plant happens to contain.

* The principle termed *tannin* has been ascertained to possess most decided acid properties, and has hence received the name of *tannic acid.* As prepared from gall-nuts, it has been found to consist of 18 equivalents of carbon, 9 of hydrogen, and 12 of oxygen (C_{18} H_9 O_{12}). It may be prepared by causing common sulphuric ether to percolate through a stratum of finely powdered galls. Pure tannic acid is very soluble in water. In the dry state it may be preserved unchanged, as it may also in solution, provided the vessel is closely corked. When its solution is exposed to the air, oxygen is absorbed, carbonic acid is evolved, and crystalline gallic acid is deposited.

† Gallic and tannic acids are distinguished from all other substances, by giving a black precipitate with persalts of iron, and these two acids are distinguished from one another by the action of gelatine—a piece of skin completely precipitating the tannic acid, while the gallic acid is left in solution.

gelatine, in an organized state, and is soluble by the long continued action of boiling water. When skin is exposed to solutions containing tannin, it slowly combines with that principle; its fibrous texture and coherence are preserved; it is rendered perfectly insoluble in water, and is no longer liable to putrefaction: in short, it becomes a substance in chemical composition precisely analogous to that furnished by the solution of jelly and the solution of tannin.

In general, in this country, the bark of the oak is used for affording tannin in the manufacture of leather; but the barks of some other trees, particularly the Spanish chesnut, have lately come into use. The following table will give a general idea of the relative value of different species of barks. It is founded on the result of experiments made by myself.

TABLE OF NUMBERS EXHIBITING THE QUANTITY OF TANNIN AFFORDED by 480 POUNDS OF DIFFERENT BARKS, WHICH EXPRESS NEARLY THEIR RELATIVE VALUES.

	lb
Average of entire bark of middle sized Oak, cut in Spring,	29
of Spanish Chesnut,	21
of Leicester Willow, large size,	33
of Elm,	13
of Common Willow, large,	11
of Ash,	16
of Beech,	10
of Horse Chesnut,	9
of Sycamore,	11
of Lombardy Poplar,	15
of Birch,	8
of Hazel,	14
of Black Thorn,	16
of Coppice Oak,	32
of Oak, cut in Autumn,	21
of Larch, cut in Autumn,	8
White interior cortical layers of Oak Bark	72

The quantity of the tanning principle in barks differs in different seasons; when the spring has been very cold the quantity is smallest. On an average, 4 or 5 lbs of good oak bark are required to form 1 lb. of leather. The inner cortical layers in all barks contain the largest quantity of tannin. Barks contain the greatest proportion of tannin at the time the buds begin to open—the smallest quantity in winter.

The extractive or colouring matters found in barks or in substances used in tanning, influence the quality of leather. Thus skin tanned with gall-nuts is much paler than skin tanned with oak bark, which contains a brown extractive matter. Leather made from catechu is of a reddish tint.

It is probable that in the process of tanning, the matter of skin, and the tanning principle first enter into union, and that the leather at the moment of its formation unites to the extractive matter.

In general, skins in being converted into leather increase in weight about one third;* and the operation is most perfect when they are tanned slowly. When skins are introduced into very strong infusions of tannin, the exterior parts immediately combine with that principle, and defend the interior parts from the action of the solution: such leather is liable to crack and to decay by the action of water.

The precipitates obtained from infusions containing tannin by isinglass, when dried, contain at a medium rate about 40 per cent. of vegetable

*This estimation must be considered as applying to *dry* skin and *dry* leather.—D.

matter. It is easy to obtain the comparative value of different substances for the use of the tanner, by comparing the quantities of precipitate afforded by infusions of given weights mixed with solutions of glue or isinglass.

To make experiments of this kind, an ounce or 480 grains of the vegetable substance in coarse powder, should be acted upon by half a pint of boiling water. The mixture should be frequently stirred, and suffered to stand 24 hours; the fluid should then be passed through a fine linen cloth and mixed with an equal quantity of solution of gelatine, made by dissolving glue, jelly, or isinglass in hot water, in the proportion of a drachm of glue or isinglass, or six table spoonfuls of jelly to a pint of water. The precipitate should be collected by passing the mixture of the solution and infusion through folds of blotting paper; and the paper exposed to the air till its contents are quite dry. If pieces of paper of equal weights are used, in cases in which different vegetable substances are employed, the difference of the weights of the papers when dried, will indicate with tolerable accuracy, the quantities of tannin contained by the substances, and their relative value, for the purposes of manufacture. Four tenths of the increase of weight, in grains, must be taken, which will be in relation to the weights in the table.

Besides the barks already mentioned, there are a number of others which contain the tanning principle. Few barks indeed are entirely free from it. It is likewise found in the wood and leaves of a number of trees and shrubs, and is one of the most generally diffused of the vegetable principles.

A substance very similar to tannin has been formed by Mr Hatchett, by the action of heated diluted nitric acid on charcoal, and evaporation of the mixture to dryness. From 100 grains of charcoal Mr Hatchett obtained 120 grains of artificial tannin, which, like natural tannin, possessed the property of rendering skin insoluble in water.

Both natural and artificial tannin form compounds with the alkalies and the alkaline earths; and these compounds are not decomposable by skin. The attempts that have been made to render oak bark more efficient as a tanning material by infusion in lime water, are consequently founded on erroneous principles. Lime forms with tannin, a compound not soluble in water.

The acids unite to tannin, and produce compounds that are more or less soluble in water. It is probable that in some vegetable substances tannin exists, combined with alkaline or earthy matter; and such substances will be rendered more efficacious for the use of the tanner, by the action of diluted acids.

9. Indigo may be procured from woad (Isatis tinctoria), by digesting alcohol on it, and evaporating the solution. White crystalline grains are obtained, which gradually become blue by the action of the atmosphere: these grains are the substance in question.

The indigo of commerce is principally brought from America. It is procured from the *Indigofera argentea*, or wild indigo, the *Indigofera disperma*, or Gautimala indigo, and the *Indigofera tinctoria*, or French indigo. It is prepared by fermenting the leaves of those trees in water. Indigo in its common form appears as a fine deep blue powder. It is insoluble in water, and but slightly soluble in alcohol: its true solvent is sulphuric acid; 8 parts of sulphuric acid dissolve 1 part of indigo; and the solution diluted with water forms a very fine blue dye.

Indigo, by its distillation, affords carbonic acid gas, water, charcoal, ammonia, and some oily and acid matter; the charcoal is in very large

proportion, Pure indigo, therefore, most probably consists of carbon, hydrogen, oxygen, and azote.

Indigo owes its blue colour to combination with oxygen.* For the uses of the dyers it is partly deprived of oxygen, by digesting it with orpiment and lime water, when it becomes soluble in the lime water, and of a greenish colour. Cloths steeped in this solution combine with the indigo; they are green when taken out of the liquor, but become blue by absorbing oxygen when exposed to air.

Indigo is one of the most valuable and most extensively used of the dyeing materials.

10 The *narcotic principle* is found abundantly in *opium*, which is obtained from the juice of the white poppy, (Papaver album). To procure the narcotic principle, water is digested upon opium: the solution obtained is evaporated till it becomes of the consistence of a syrup. By the addition of cold water to this syrup a precipitate is obtained. Alcohol is boiled on this precipitate; during the cooling of the alcohol crystals fall down. These crystals are to be again dissolved in alcohol, and again precipitated by cooling: and the process is to be repeated till their colour is white: they are crystals of narcotic principle.

The narcotic principle has no taste nor smell. It is soluble in about 400 parts of boiling water; it is insoluble in cold water: it is soluble in 24 parts of boiling alcohol, and in 100 parts of cold alcohol. It is very soluble in all acid menstrua.

It has been shewn by De Rosne, that the action of opium on the animal economy depends on this principle. Many other substances besides the juice of the poppy, possess narcotic properties; but they have not yet been examined with much attention.† The Lactuca sativa, or garden lettuce, and most of the other lactucas yield a milky juice, which, when inspissated, has the characters of opium, and probably contains the same narcotic principle.

* The indigo of commerce is a very complex substance. It contains according to Berzelius, indigo blue, (the active principle), indigo red, indigo brown, a substance allied to gluten, together with salts of lime and magnesia. The process by which these substances are separated from one another it is unnecessary to describe. The indigo blue does not exist in the juice of the plant, but is the result of oxidation, the infusion being carefully exposed to the air until it acquires a blue colour and the powder subsides. To the substance which is believed to exist in the plant and by whose oxidation indigo blue is generated, Liebig has assigned the name *Indigogen*. It is represented by the formula C_{45} H_{15} N_3 O_4. Indigogen unites readily with the alkalies, and forms highly soluble compounds. In this state it is used as a dye. The solution is yellow, but it absorbs oxygen with great facility, and passes into indigo blue, the composition of which is the same, with the addition of two equivalents of oxygen. Indigo blue is soluble in sulphuric acid, and the solution is employed extensively in dyeing.

† Several vegetable alkalies have been found in opium; one by Derosne, now called narcotina, another by Sertuerner, called morphia, and the remarks in the text appear to apply partly to the one and partly to the other. The pure narcotic influence of opium is attributed to the morphia, while the stimulating effects are by many regarded as due to the narcotina. It is scarcely accurate to speak of a narcotic principle, if by such we mean a single vegetable proximate of definite composition, existing in a variety of drugs whose action is narcotic. Many of these no doubt contain vegetable alkalies, but their composition is various. Vegetable alkalies have been separated from a number of plants. Cinchona bark affords *quina*, *cinchonia*, and *aricina*; nux vomica affords

11. The *bitter principle* is very extensively diffused in the vegetable kingdom; it is found abundantly in the hop (Humilus lupilus), in the common broom (Spartium scoparium), in the chamomile (Anthemis nobilis), and in quassia amara, and excelsa. It is obtained from those substances by the action of water or alcohol, and evaporation. It is usually of a pale yellow colour: its taste is intensely bitter. It is very soluble, both in water and alcohol; and has little or no action on alkaline, acid, saline, or metallic solutions.

An artificial substance, similar to the bitter principle, has been obtained by digesting diluted nitric acid, on silk, indigo, and the wood of the white willow. This substance has the property of dyeing cloth of a bright yellow colour; it differs from the natural bitter principle in its powers of combining with the alkalies: in union with the fixed alkalies it constitutes crystalized bodies, which have the property of detonating by heat or percussion.

The natural bitter principle is of great importance in the art of brewing, it checks fermentation, and preserves fermented liquors; it is likewise used in medicine.

The bitter principle, like the narcotic principle, appears to consist principally of carbon, hydrogen, and oxygen, with a little azote.*

12. WAX is found in a number of vegetables; it is procured in abundance from the berries of the wax myrtle (Myrica cerifera): it may be likewise obtained from the leaves of many trees; in its pure state it is white. Its specific gravity is ·9662; it melts at 155 degrees; it is dissolved by boiling alcohol; but it is not acted upon by cold alcohol: it is insoluble in water; its properties as a combustible body are well known.

The wax of the vegetable kingdom seems to be precisely of the same nature as that afforded by the bee.

From the experiments of MM. Gay Lussac and Thenard, it appears that 100 parts of wax consist of

Carbon	81·784
Oxygen	5·544
Hydrogen	12·672

or otherwise,

Carbon	81·784
Oxygen and Hydrogen in the proportions necessary to form water	6·300
Hydrogen	11·916

which agrees very nearly with 37 proportions of hydrogen, 21 of charcoal, 1 of oxygen. †

strychnia; ipecacuan affords *emetia,* tobacco, *nicotiana,* and so of others. These alkalies are prepared by processes which it would be foreign to the objects of the work to detail. With respect to medicinal properties, they are to be regarded as the active principles of the drugs from which they are extracted, and their action on the body differs as much as the crude drugs. Thus morphia is narcotic, quina tonic, emetia emetic, &c.

The presence of alkalies whether organic or inorganic in plants is a subject of great importance to the agricultural chemist. For new and important views on this subject we are indebted to Liebig.

* The term bitter principle cannot be applied exclusively to any known proximate, for many proximates of different composition have a bitter taste. The soluble salts of many of the vegetable alkalies are intensely bitter. Salicine, a principle found in the bark of the willow is also bitter, and many plants afford substances soluble in water and alcohol extremely bitter, from which proximates have not yet been extracted.

† The formula representing the composition of wax is C_{20} H_{20} O which does

13. Resin is very common in the vegetable kingdom. One of the most usual species is that afforded by the different kinds of fir. When a portion of the bark is removed from a fir tree in spring, a matter exudes, which is called turpentine; by heating this turpentine gently, a volatile oil rises from it, and a more fixed substance remains; this substance is resin.

The resin of the fir is the substance commonly known by the name of rosin; its properties are well known. Its specific gravity is 1 072. It melts readily, burns with a yellow light, throwing off much smoke. Resin is insoluble in water, either hot or cold; but very soluble in alcohol. When a solution of resin in alcohol is mixed with water, the solution becomes milky; the resin is deposited by the stronger attraction of the water for the alcohol.

Resins are obtained from many other species of trees. *Mastich*, from the *Pistacia lentiscus*, *Elemi* from the *Amyris elemifera*, *Copal* from the *Rhus copallinum*, *Sandarach* from the common juniper. Of these resins copal is the most peculiar. It is the most difficultly dissolved in alcohol; and for this purpose must be exposed to that substance in vapour; or the alcohol employed must hold camphor in solution. According to Gay Lussac and Thenard,

100 parts of common resin contain

	Carbon	75·944
	Oxygen	13·337
	Hydrogen	10 719
or of	Carbon	75 944
	Oxygen and Hydrogen in the proportions necessary to form water	15 156
	Hydrogen in excess	8·900

According to the same chemists, 100 parts of copal consist of

	Carbon	76 811
	Oxygen	10·606
	Hydrogen	12·583
or,	Carbon	76 811
	Water or its elements	12 052
	Hydrogen	11·137

From these results, if resin be a definite compound, it may be supposed to consist of 8 proportions of carbon, 12 of hydrogen, and 1 of oxygen.*

Resins are used for a variety of purposes. Tar and pitch principally consist of resin, in a partially decomposed state. Tar is made by the slow combustion of the fir; and pitch by the evaporation of the more volatile parts of tar. Resins are employed as varnishes, and for these purposes are dissolved in alcohol or oils. Copal forms one of the finest. It may be made by boiling it in powder with oil of rosemary, and then adding alcohol to the solution.

14. Camphor is procured by distilling the wood of the camphor tree (Laurus camphora), which grows in Japan. It is a very volatile body, and may be purified by distillation Camphor is a white, brittle, semi-transparent substance, having a peculiar odour, and a strong acrid taste.

not differ much from the analysis in the text, and agrees still more closely with that of Hess.

* From more recent examinations of common resin, it would appear to consist of three principles, namely, sylvic acid, separable by diluted alcohol: pinic acid, which remains when resin is treated with spirit of wine: and colopholic acid, which is produced when resin is subjected to heat. These three principles are isomeric, and may be represented by the formula $C_{20} H_{15} O_2$.—(Liebig).

It is very slightly soluble in water: more than 100,000 parts of water are required to dissolve 1 part of camphor. It is very soluble in alcohol: and by adding water in small quantities at a time to the solution of camphor in alcohol, the camphor separates in a crystallised form. It is soluble in nitric acid, and is separated from it by water.

Camphor is very inflammable; it burns with a bright flame, and throws off a great quantity of carbonaceous matter. It forms in combustion water, carbonic acid, and a peculiar acid called *camphoric* acid. No accurate analysis has been made of camphor, but it seems to approach to the resins in its composition; and consists of carbon, hydrogen and oxygen.*

Camphor exists in other plants besides the Laurus camphora. It is procured from species of the laurus growing in Sumatra, Borneo, and other of the East Indian Isles. It has been obtained from thyme (Thymus serpillum), marjorum (Origanum majorana), Ginger tree (Amomum Zingiber), Sage (Salvia officinalis).† Many volatile oils yield camphor by being merely exposed to the air.

An artificial substance, very similar to camphor has been formed by M. Kind, by saturating oil of turpentine with muriatic acid gas (the gaseous substance procured from common salt by the action of sulphuric acid). The camphor procured in well conducted experiments amounts to half of the oil of turpentine used. It agrees with common camphor in most of its sensible properties; but differs materially in its chemical qualities and composition. It is not soluble without decomposition in nitric acid. From the experiments of Gehlen, it appears to consist of the elements of oil of turpentine—carbon, hydrogen, and oxygen—united to the elements of muriatic gas—chlorine and hydrogen. ‡

From the analogy of artificial to natural camphor, it does not appear improbable, that natural camphor may be a secondary vegetable compound, consisting of camphoric acid and volatile oil. Camphor is used medicinally, but it has no other application.

15. FIXED OIL is obtained by expression from seeds and fruits; the olive, the almond, linseed and rape-seed afford the most common vegetable fixed oils. The properties of fixed oils are well known. Their specific gravity is less than that of water; that of olive and of rape-seed oil is ·913; that of linseed and almond oil ·932; that of palm oil ·968; that of walnut and beech mast oil ·923. Many of the fixed oils congeal at a lower temperature than that at which water freezes. They all require for their evaporation a higher temperature than that at which water boils. The products of the combustion of oil are water and carbonic acid gas.

From the experiments of Gay Lussac and Thenard, it appears that olive oil contains, in 100 parts,

Carbon	77·213
Oxygen	9·427
Hydrogen	13·360

* Camphor has been examined by several chemists, particularly by Dumas. It is represented by the formula C_{10} H_8 O. He considers it as an oxide of *camphene* (pure oil of turpentine), which is represented by the formula C_{10} H_8; while other chemists do not regard camphor as formed by the direct oxidation of camphene.

† Dumas finds that oil of lavender deposits a solid substance identical with common camphor, and it has been found that the essential oils which contain no oxygen, deposit, on exposure to air, substances allied to resin.

‡ Artificial camphor is represented by the formula C_{20} H_{17} Cl. Camphoric acid, which is got by treating camphor with nitric acid, has the formula C_{10} H_7 O_3.

This estimation is a near approximation to 11 proportions of carbon, 20 hydrogen, and 1 oxygen.*

The following is a list of fixed oils, and of the trees that afford them:—

Olive oil, from the Olive tree (Olea Europea), Linseed oil, from the common and perennial Flax (Linum usitatissimum et perenne), Nut oil from the Hazel nut (Coryllus avellana), Walnut (Juglans regia), Hemp oil, from the Hemp (Cannabis sativa), Almond oil, from the sweet Almond (Amygdalus communis), Beech oil, from the common Beech (Fagus sylvatica), Rape-seed oil, from the Rapes (Brassica napus et campestris), Poppy oil, from the Poppy (Papaver somniferum), oil of Sesamum, from the Sesamum (Sesamum orientale), Cucumber oil, from the Gourds (Cucurbita pepo et malapepo), oil of Mustard, from the Mustard (Sinapis nigra et arvensis), oil of Sunflower, from the annual and perennial Sunflower (Helianthus annuus et perennis), Castor oil, from the Palma Christi (Ricinus communis), Tobacco-seed oil, from the Tobacco (Nicotiana tabacum et rustica), Plum kernel oil, from the Plum tree (Prunus domestica), Grape-seed oil, from the Vine (Vitis vinifera), Butter of cacoa, from the Cacoa tree (Theobroma cacao), Laurel oil, from the sweet Bay tree (Laurus nobilis).

The fixed oils are very nutritive substances; they are of great importance in their applications to the purposes of life. Fixed oil, in combination with soda, forms the finest kind of hard soap.† The fixed oils are used extensively in the mechanical arts, and for the preparation of pigments and varnishes.

16. VOLATILE OIL, likewise called *essential oil*, differs from fixed oil, in being capable of evaporation by a much lower degree of heat; in being soluble in alcohol, and in possessing a very slight degree of solubility in water.

There is a great number of volatile oils, distinguished by their smell, their taste, their specific gravity, and other sensible qualities. A strong and peculiar odour may, however, be considered as the great characteristic of each species; the volatile oils inflame with more facility than the fixed oils, and afford by their combustion different proportions of the same substances, water, carbonic acid, and carbon.

The following specific gravities of different volatile oils were ascertained by Dr. Lewis.

Oil of Sassafras	1094	Oil of Tansy	946
.. Cinnamon	1035	.. Carraway	940
.. Cloves	1034	.. Origanum	940
.. Fennel	997	.. Spike	936
.. Dill	994	.. Rosemary	934
.. Penny royal	978	.. Juniper	911
.. Cummin	975	.. Oranges	888
.. Mint	975	.. Turpentine	792
.. Nutmegs	948		

* All the fixed oils are very complex bodies. Generally speaking, they consist of oleic, margaric, and stearic acids, in combination with oxide of glycerule. The thicker oils and fats contain most stearate, and margarate of oxide of glycerule: those that are most liquid, contain most oleate of oxide of glycerule.

Some of the fixed oils readily absorb oxygen from the air, and thicken into a solid varnish, hence they are called *drying* oils. The most important of these are linseed, walnut, hempseed, and poppyseed oils. The fish oils, animal oils, and fat vegetable oils, do not possess this drying property.

† Soaps formed from soda are harder and less soluble than corresponding ones of potash, and soaps containing stearic and margaric acids are harder than those containing oleic acid. Soft soaps are prepared from the drying oils.

The peculiar odours of plants seem, in almost all cases, to depend upon the peculiar volatile oils they contain. All the perfumed distilled waters owe their peculiar properties to the volatile oils they hold in solution. By collecting the aromatic oils, the fragrance of flowers, so fugitive in the common course of nature, is as it were embodied and made permanent.

It cannot be doubted that the volatile oils consist of carbon, hydrogen, and oxygen; but no accurate experiments have as yet been made on the proportions in which these elements are combined. *

The volatile oils have never been used as articles of food; many of them are employed in the arts, in the manufacture of pigments and varnishes; but their most extensive application is as perfumes.

17. WOODY FIBRE is procured from the wood, bark, leaves, or flowers of trees, by exposing them to the repeated action of boiling water and boiling alcohol. It is the insoluble matter that remains, and is the basis of the solid organized parts of plants. There are as many varieties of woody fibre as there are plants, and organs of plants; but they are all distinguished by their fibrous texture, and their insolubility.

Woody fibre burns with a yellow flame, and produces water and carbonic acid in burning. When it is distilled in close vessels, it yields a considerable residuum of charcoal. It is from woody fibre, indeed, that charcoal is procured for the purposes of life.

The following table contains the results of experiments made by Mr Mushet, on the quantity of charcoal afforded by different kinds of wood:—

100 parts of	Lignum Vitæ	26·8	of charcoal
.. ..	Mahogany	25·4	..
.. ..	Laburnum	24·5	..
.. ..	Chesnut	23·2	..
.. ..	Oak	22·6	..
.. ..	American black Beech	21·4	..
.. ..	Walnut	20·6	..
.. ..	Holly	19·9	.
.. ..	Beech	19·9	..
.. .	American Maple	19·9	..
.. ..	Elm	19·5	..
.. ..	Norway Pine	19·2	..
.. ..	Sallow	18·4	..
.. ..	Ash	17·9	..
.. ..	Birch	17·4	..
.. ..	Scottish Fir	16·4	..

MM. Gay Lussac and Thenard have concluded from their experiments on the wood of the oak and the beech, that 100 parts of the first contain:

of Carbon	52·53
.. Oxygen	41·78
.. Hydrogen	5·69

* Some of the essential oils, especially the lighter ones, contain no oxygen. Oil of turpentine may be taken as the type of this group. Several of them have been analysed, and give proportions of carbon and hydrogen in 100 parts, which correspond to the formula C_{10} H_8. These absorb oxygen from the air, and become thickened and contaminated with resinous substances. Certain also of the essential oils contain oxygen. They generally consist of several oils differing in volatility, and have not yet been much studied. Some of the oils of this group, such as the oils of lavender, valerian, thyme, &c., deposit camphor, and substances allied to it. A much smaller group of the essential oils, such as the oil of mustard seed, is formed of those containing sulphur and nitrogen.

and 100 parts of the second:

of Carbon	51·45
.. Oxygen	42·73
.. Hydrogen	5·82

Supposing woody fibre to be a definite compound, these estimations lead to the conclusion, that it consists of 5 proportions of carbon, 3 of oxygen, and 6 of hydrogen; or 57 carbon, 45 oxygen, and 6 hydrogen.*

It will be unnecessary to speak of the applications of woody fibre. The different uses of the woods, cotton, linen, the barks of trees, are sufficiently known. Woody fibre appears to be an indigestible substance.

18. The acids found in the vegetable kingdom are numerous; the true vegetable acids which exist ready formed in the juices, or organs of plants, are the *oxalic*, *citric*, *tartaric*, *benzoic*, *acetic*, *malic*, *gallic*, and *prussic* acid.†

All these acids, except the acetic, malic, and prussic acids, are white crystallised bodies. The acetic, malic, and prussic acids have been obtained only in the fluid state;‡ they are all more or less soluble in water; all have a sour taste except the gallic and prussic acids; of which the

* It is necessary here to caution the student against an error into which it is possible he might fall, namely, that woody fibre, and fibrine, formerly mentioned, are identical. The term woody fibre is applied by many writers to the tissue which constitutes the principal part of wood. *Woody tissue* is a less ambiguous term. The term fibrine applies to a vegetable proximate, identical in composition with the fibrine of the blood, or of the muscles of animals. Vegetable fibrine, according to Liebig, may be prepared from vegetable juices, from which it separates on standing, or from the so-called gluten of wheat flour, by dissolving out the true gluten by hot alcohol.

Woody tissue, as it occurs in the wood of different trees, contains a quantity of *incrusting* matter, varying with the age of the wood, the species of the tree, and other circumstances. Thus the heart-wood contains more than the sap-wood, and the wood of the oak more than pine-wood. The incrusting matter consists of the same elements as the wood, but the hydrogen exists in it in greater proportion than with the oxygen would form water. According to the analysis of Prout, woody tissue freed from incrusting matter by the action of water and alcohol, may be represented by the formula C_{12} H_8 O_8; but other chemists, and among the number Liebig, seem to prefer the analysis of MM. Gay Lussac and Thenard, given in the text, which was also made on wood from which the soluble matters had been removed. Their analysis correspond to the formula C_{36} H_{22} O_{22}.

Vegetable anatomists distinguish between woody tissue and cellular tissue, the former consisting of elongated cells or tubes, more or less conical at both extremities, the latter of cells never elongated to any great extent. Although in shape, size, quantity of incrusting matter, &c., both vary, they may perhaps be referred to the same type. Anatomists, however, find certain forms of cellular tissue in which fibre occurs, a circumstance not hitherto observed of woody tissue; and some chemists have found cellular tissue to differ in composition from woody tissue, in containing a larger proportion of the elements of water.

In a physical point of view, woody tissue is very different from cellular tissue, in consequence of the elongated form of the vessels, and the more extensive lateral adhesion, textures formed of it possess much greater strength and elasticity, and are more advantageously used as cordage, &c.; thus lint, and flax, are stronger than cotton, either in thread, cloth, or paper.

† A great number of other vegetable acids have since been discovered, but it would be out of place here to enter into particulars regarding them.

‡ Acetic and malic acids have both been obtained in the solid form. The former crystallises at low temperatures in combination with one equivalent of water; the latter is deliquescent, and very soluble.

first has an astringent taste, and the latter a taste like that of bitter almonds.

The oxalic acid exists, uncombined, in the liquor which exudes from the Chich pea (Cicer arietinum), and may be procured from wood sorrel (Oxalis acetosella), common sorrel, and other species of rumex; and from the Geranium acidum. Oxalic acid is easily discovered and distinguished from other acids by its property of decomposing all calcareous salts, and forming with lime a salt insoluble in water; and by its crystallising in four-sided prisms.*

The citric acid is the peculiar acid existing in the juice of lemons and oranges. It may likewise be obtained from the cranberry, whortleberry, and hip.

Citric acid is distinguished by its forming a salt insoluble in water with lime, but decomposable by the mineral acids.

The tartaric acid may be obtained from the juice of mulberries and grapes; and likewise from the pulp of the tamarind. It is characterized by its property of forming a difficultly soluble salt with potassa, and an insoluble salt decomposable by the mineral acids with lime.

Benzoic acid may be procured from several resinous substances by distillation; from benzoin, storax, and balsam of Tolu. It is distinguished from the other acids by its aromatic odour, and by its extreme volatility.

Malic acid may be obtained from the juice of apples, barberries, plums, elderberries, currants, strawberries, and raspberries. It forms a soluble salt with lime; and is easily distinguished by this test from the acids already named.

Acetic acid, or vinegar, may be obtained from the sap of different trees. It is distinguished from malic acid by its peculiar odour; and from the other vegetable acids by forming soluble salts with the alkalies and earths.

Gallic acid may be obtained by gently and gradually heating powdered gall-nuts, and receiving the volatile matter in a cool vessel. A number of white crystals will appear, which are distinguished by their property of rendering solutions of iron deep purple.

The vegetable prussic acid is procured by distilling laurel leaves, or the kernels of the peach, and cherry, or bitter almonds. It is characterized by its property of forming a blueish green precipitate, when a little alkali is added to it, and it is poured into solutions containing iron. It is very analogous in its properties to the prussic acid obtained from animal substances; or by passing ammonia over heated charcoal; but this last body forms, with the red oxide of iron, the deep bright blue substance, called Prussian blue. †

Two other vegetable acids have been found in the products of plants; the morolyxic acid in a saline exudation from the white mulberry tree, and the kinic acid in a salt afforded by Peruvian bark; but these two bodies have as yet been discovered in no other cases. The phosphoric

* Oxalic acid is also well characterized by being resolved without residue into carbonic acid and carbonic oxide, when heated with sulphuric acid. The prismatic form of the crystals is frequently not well defined in the acid of commerce, but by solution in hot distilled water, and recrystallisation, oxalic acid is got in fine prisms, and much purer. But it generally still contains some potash from which it is scarcely possible to free it by crystallisation. Oxalic acid is readily procured by heating sugar or starch, with diluted nitric acid.

† The prussic acid obtained by distilling bitter almonds and water, is in no respect different from that obtained by other methods, only, unless means are taken to prevent it, the acid comes over mixed with foreign bodies.

acid is found free in the onion; and the phosphoric, sulphuric, muriatic, and nitric acids, exist in many saline compounds in the vegetable kingdom; but they cannot with propriety be considered as vegetable products.* Other acids are produced during the combustion of vegetable compounds, or by the action of nitric acid upon them; they are the camphoric acid, the mucous or saclactic acid, and the suberic acid; the first of which is procured from camphor; the second from gum or mucilage; and the third from cork, by the action of nitric acid.

From the experiments that have been made upon the vegetable acids, it appears that all of them, except the prussic acid, are constituted by different proportions of carbon, hydrogen, and oxygen; the prussic acid consists of carbon, azote and hydrogen, with a little oxygen. The gallic acid contains more carbon than any of the other vegetable acids.

The following estimates of the composition of some of the vegetable acids have been made by Gay Lussac and Thenard.

100 parts of oxalic acid contain:

Carbon	26 566
Hydrogen	2·745
Oxygen	70 689

Ditto of tartaric acid:

Carbon	24·050
Hydrogen	6.629
Oxygen	69·321

Ditto citric acid:

Carbon	33·811
Hydrogen	6·330
Oxygen	59·859

100 parts of acetic acid:

Carbon	50·224
Hydrogen	5 629
Oxygen	44·147

Ditto mucous or saclactic acid:

Carbon	33·69
Hydrogen	3·62
Oxygen	62 69

These estimations agree nearly with the following definite proportions. In oxalic acid 7 proportions of carbon, 8 of hydrogen, and 15 oxygen;† in tartaric acid, 8 carbon, 28 hydrogen, 18 oxygen; in citric acid, 3 car-

* Though not strictly vegetable products, these last mentioned acids are of great importance to the agriculturist. They are found in small quantity, but yet are necessary to the healthy developement of the plants in which they occur, as any other of their constituents. Phosphorus has been already noticed as occurring in albumen, and fibrine, and sulphur, in these as well as in caseine. These three vegetable proximates indeed constitute the source from which animals derive them. It is not wonderful then, that small doses of bone dust, gypsum, salt, and nitrate of soda, act so energetically as manures, when applied to soils that do not contain them, or have been deprived of them by continued cropping.

† According to Dr. Thomson's experiments, oxalic acid consists of 3 proportions of carbon, 4 of oxygen, and 4 of hydrogen, a result very different indeed from that of the French chemists.—D.

bon, 6 hydrogen, 4 oxygen; in acetic acid, 18 carbon, 22 hydrogen, 12 oxygen; in mucous acid, 6 carbon, 7 hydrogen, 8 oxygen. *

The applications of the vegetable acids are well known. The acetic and citric acids are extensively used. The agreeable taste and wholesomeness of various vegetable substances used as food, materially depend upon the vegetable acid they contain.

19. FIXED ALKALI may be obtained in aqueous solution from most plants by burning them, and treating the ashes with quick lime and water. The vegetable alkali, or potassa, is the common alkali in the vegetable kingdom. This substance in its pure state is white, and semi-transparent, requiring a strong heat for its fusion, and possessed of a highly caustic taste. In the matter usually called pure potassa by chemists, it exists combined with water; and in that commonly called pearl ashes, or pot-ashes in commerce, it is combined with a small quantity of carbonic acid. Potassa, in its uncombined state, as has been mentioned, page 27, consists of the highly inflammable metal, potassium, and oxygen, one proportion of each.

Soda, or the mineral alkali, is found in some plants that grow near the sea; and is obtained combined with water, or carbonic acid, in the same manner as potassa; and consists as has been stated, page 27, of one proportion of sodium, and two proportions of oxygen [of single equivalents.—S]. In its properties it is very similar to potassa; but may be easily distinguished from it by this character: it forms a hard soap with oil; potassa forms a soft soap.

Pearl ashes, and barilla and kelp, or the impure soda obtained from the ashes of marine plants, are very valuable in commerce, principally on account of their uses in the manufacture of glass and soap. Glass is made from fixed alkali, flint, and certain metallic substances.

To know whether a vegetable yields alkali, it should be burnt, and the ashes washed with a small quantity of water. If the water, after being for some time exposed to the air, reddens paper tinged with turmeric; or renders vegetable blues, green, it contains alkali.

To ascertain the relative quantities of pot-ashes afforded by different plants, equal weights of them should be burnt: the ashes washed in twice their volume of water; the washings should be passed through blotting paper, and evaporated to dryness: the relative weights of the salt obtained, will indicate very nearly the relative quantities of alkali they contain.

The value of marine plants in producing soda, may be estimated in the same manner, with sufficient correctness for all commercial purposes.

Herbs, in general, furnish four or five times, and shrubs two or three times as much pot-ashes as trees. The leaves produce more than the branches, and the branches more than the trunk. Vegetables burnt in a green state produce more ashes than in a dry state.

The following table, founded upon the experiments of Kirwan, Vau-

* The composition of the vegetable acids mentioned in the text is indicated by the following formulæ:—

Oxalic acid	$C_2 — O_3$
Citric acid	$C_{12} H_5 O_{11}$
Tartaric acid	$C_8 H_4 O_{10}$
Benzoic acid	$C_{14} H_5 O_3$
Malic acid	$C_8 H_4 O_8$
Acetic acid	$C_4 H_3 O_3$
Gallic acid	$C_7 H O_3$
Prussic acid	$C_2 H — N$.

quelin, and Pertuis, contains a statement of the quantity of pot-ashes afforded by some common trees and plants:—

10,000 parts of Oak	15	10,000 parts of Fern	62
.. .. of Elm	39	.. .. of Cow Thistle	196
.. .. of Beech	12	.. .. of Wormwood	730
.. .. of Vine	55	.. .. of Vetches	275
.. .. of Poplar	7	.. .. of Beans	200
.. .. of Thistle	53	.. .. of Fumitory	790

The EARTHS found in plants are four: silica or the earth of flints, alumina or pure clay, lime and magnesia. They are procured by incineration. The lime is usually combined with carbonic acid. This substance, and silica are much more common in the vegetable kingdom than magnesia, and magnesia more common than alumina. The earths form a principal part of the matter insoluble in water, afforded by the ashes of plants. The silica is known by not being dissolved by acids; the calcareous earth, unless the ashes have been very intensely ignited, dissolves with effervesence in muriatic acid. Magnesia forms a soluble and crystallisable salt, and lime, a difficultly soluble one with sulphuric acid. Alumina is distinguished from the other earths, by being acted upon very slowly by acids; and in forming salts very soluble in water, and difficult of crystallisation with them.

The earths appear to be compounds of the peculiar metals mentioned page 25, and oxygen, one proportion of each.

The earths afforded by plants are applied to no uses of common life; and there are few cases in which the knowledge of their nature can be of importance, or afford interest to the farmer.

The only *metallic oxides* found in plants, are those of iron and manganesum; they are detected in the ashes of plants; but in very minute quantities only. When the ashes of plants are reddish brown, they abound in oxides of iron. When black or purple, in oxides of manganesum; when these colours are mixed, they contain both substances.

The saline compounds contained in plants, or afforded by their incineration, are very various. The sulphuric acid combined with potassa, or sulphate of potassa, is one of the most usual. Common salt is likewise very often found in the ashes of plants; likewise phosphate of lime, which is insoluble in water, but soluble in muriatic acid. Compounds of the nitric, muriatic, sulphuric, and phosphoric acids, with alkalies and earths, exist in the sap of many plants, or are afforded by their evaporation and incineration. The salts of potassa are distinguished from those of soda by their producing a precipitate in solutions of platina: those of lime are characterized by the cloudiness they occasion in solutions containing oxalic acid; those of magnesia, by being rendered cloudy by solutions of ammonia. Sulphuric acid is detected in salts by the dense white precipitate it forms in solutions of baryta. Muriatic acid by the cloudiness it communicates to solution of nitrate of silver; and when salts contain nitric acid, they produce scintillations by being thrown upon burning coals.

As no applications have been made of any of the neutral salts, or analogous compounds found in plants, in a separate state, it will be useless to describe them individually. The following tables are given from M. Th. de Saussure's Researches on Vegetation, and contain results obtained by that philosopher. They exhibit the quantities of soluble salts, metallic oxides and earths, afforded by the ashes of different plants.

	NAMES OF PLANTS.	Ashes from one thousand parts of the Plant green.	Ditto, dry.	Water from one thousand parts of the Plant green.	Constituents of 100 parts of the Ashes. Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silica.	Metallic Oxides.	Loss.
1	Leaves of oak *(quercus robur)* May 10	13	53	745	47	24	0·12	3	0·64	25.24
2	Ditto, Sept. 27	24	55	549	17	18·25	23	14·5	1·75	25·5
3	Wood of a young oak, May 10	..	4	..	26	28·5	12·25	0·12	1	32·58
4	Bark of ditto	..	60	..	7	4·5	63·25	0·25	1·75	22·75
5	Entire wood of oak	..	2	..	38·6	4·5	32	2	2·25	20·65
6	Alburnum of ditto	..	..	..	32	24	11	7·5	2	23·5
7	Bark of ditto	..	60	..	7	3	66	1.5	2	21·5
8	Cortical layers of ditto	..	73	..	7	3·75	65	0·5	1	22·75
9	Extract of wood of ditto	..	61	..	51					
10	Soil from wood of ditto	..	41	..	24	10·5	10	32	14	8·5
11	Extract from ditto	..	111	..	66					
12	Leaves of the poplar *(populus nigra)* May 26	23	66	652	36	13	29	5	1·25	15·75
13	Ditto, Sept. 12	41	93	565	26	7	36	11·5	1·5	18
14	Wood of ditto, Sept. 12	..	8	26	..	16·75	27	3·3	1·5	24·5
15	Bark of ditto	..	72	..	6	5·3	60	4	1·5	23·2
16	Leaves of hazel *(corylus avellana)*, May 1	..	61	..	26	23·3	22	2·5	1·5	24·7
17	Ditto washed in cold water	..	57	..	8·2	19·5	44·1	4	2	22·2
18	Leaves of ditto, June .22	28	62	655	22·7	14	29	11·3	1·5	21·5
19	Do. Sept. 20	31	70	557	11	12	36	22	2	17
20	Wood of do. May 1	..	5	..	24·5	35	8	0·25	0·12	32·2
21	Bark of do.	..	62	..	12·5	5·5	54	0·25	1 75	26
22	Entire wood of mulberry (*morus nigra*), November	..	7	..	21	2·25	56	0·12	0·25	20·38
23	Alburnum of do.	..	13	..	26	27·25	24	1	0·25	21·5
24	Bark of do.	..	89	..	7	8·5	45	15·25	1·12	23·13
25	Cortical layers of do.	..	88	..	10	16·5	48	0·12	1	24·38
26	Entire wood of hornbeam, (*carpinus betulus*), Nov.	4	6	346	22	23	26	0·12	2·25	26·63
27	Alburnum of do.	4	7	390	18	36	15	1	1	29
28	Bark of do.	88	134	346	4 5	4·5	59	1·5	0·12	30·38
29	Wood of horse chessnut (*aesculus hyppocastanum*), May 10	...	35	..	9·5					
30	Leaves of do. May 10	16	72	782	50					
31	Leaves of do. July 23	29	84	652	24					
32	Do. Sept. 27	31	86	630	13·5					
33	Flowers of do. May 10	9	71	873	50					
34	Fruit of do. Oct. 5	12	34	647	82	12	..	0·5	0·25	5·25
35	Plants of Peas (*pisum sativum*), in flower,	..	95	...	49·8	17·25	6	2·3	1	24·65
36	Plants of Peas (*pisum sativum*), in flower, ripe	..	81	..	34·25	22	14	11	2·5	17·25
37	Plants of vetches (*vicia faba*), before flowering, May 23	16	150	895	55·5	14·5	3·5	1·5	0·5	24·50
38	Do. in flower, June 23	20	122	876	55·5	13 5	4·12	1.5	0·5	24·38
39	Do. ripe, July 23	..	66	..	50	17·75	4	1·75	0·5	26
40	Do. seeds separated	..	115	..	42	5 75	36	1·75	I	12·9
41	Seeds of. do.	..	33	..	69·28	27·92	..	..	0·5	2·3

	NAMES OF PLANTS	Ashes from one thousand parts of the Plant green.	Ditto, dry.	Water from one thousand parts of the plant green.	Constituents of 100 parts of the Ashes: Soluble Salts.	Earthy Phosphates.	Earthy Carbonates.	Silica.	Metallic Oxides.	Loss.
42	Plants of vetches in flower, raised in distilled water		39		60 1	30			0 5	9 4
43	*Solidago vulgaris*, before flowering, May 1		92		67 5	10 75	1 5	1 5	0 75	18 25
44	Do just in flower, July 15		57		59	59	1 5	1 5	0 75	21
45	Do seeds ripe, Sept 20 .		50		48	11	17 25	3 5	1 5	18 75
46	Plants of turnsol (*helianthus annuus*), a month before flowering, June 23	..	147		63	67	11 56	1 5	0 12	16 67
47	Do in flower, July 23	13	137	877	61	6	12 5	1 5	0 12	18 78
48	Do bearing ripe seeds, Sept 20	23	93	753	5 15	22 5	4	3 75	0 5	17 75
49	Wheat (*triticum sativum*), in flower . .				43 25	12 75	0 25	32	0 5	12 25
50	Do seeds ripe .		..		11	15	0 25	54	1	18 75
51	Do a month before flowering	..	79		60	11 5	0 25	12 5	0 25	15 5
52	Do in flower, June 14	16	54	699	41	10 75	0 25	26	0 5	21 5
53	Do seeds ripe .		33		10	11 75	0 25	51	0 75	23
54	Straw of wheat		43		22 5	6 2	1	61 5	1	78
55	Seeds of do .		13		47 16	44 5		0 5	0 25	7 6
56	Bran .		52		4 16	46 5		0 5	0 25	8 6
57	Plants of maize (*zea mays*), a month before flowg , June 23		122		69	5 75	0 25	7 5	0 25	17 25
58	Do in flower, July 23		81		69	6	0 25	7 5	0 25	17
59	Do seeds ripe .		46							
60	Stalks of do		84		72 45	5	1	18	0 5	3 05
61	Spikes of do		16							
62	Seeds of do		10		62	36		1	0 12	0 88
63	Chaff of barley (*hordeum vulgare*) .		42		20	7 75	12 5	57	0 5	2 25
64	Seeds of do.		18		29	32 5		35 5	0 25	2 8
65	Do .		..		22	22		21	0 12	29 88
66	Oats .	.	31		1	24		60	0 25	14 75
67	Leaves of *rhododendron ferrugineum*, raised on Jura, a limestone mountain, June 20		30		23	14	43 25	0 75	3 25	15 63
68	Do raised on Breven, a granitic mountain, June 27 .		25		21·1	16 75	16 75	2	5 77	31 52
69	Branches of do , June 20 .		8		22 5	10	39	0 5	5 4	22 48
70	Spikes of do , June 27		8		24	11 5	29	1	11	24 5
71	Leaves of fir (*pinus abies*) raised on Jura, June 20		29		16	12 27	43 5	2 5	1 6	24 13
72	Do raised on Breven, June 27		29		15	12	29	19	5 5	19 5
73	Branches of pine, June 20		15		15					
74	Whortleberry (*vaccinium myrtilus*) raised on Jura, Aug 29		26		17	18	42	0 5	3 12	19 38
75	Do. raised on Breven	..	22	..	24	22	22	5	9 5	17 5

Besides the principles, the nature of which has been just discussed, others have been described by chemists as belonging to the vegetable kingdom: thus a substance, somewhat analogous to the muscular fibre of animals, has been detected by Vauquelin in the papaw; and a matter similar to animal gelatine by Braconnot in the mushroom; but in this place it would be improper to dwell upon peculiarities; my object being to offer such general views of the constitution of vegetables as may be of use to the agriculturist Some distinctions have been adopted by systematical authors, which I have not entered into, because they do not appear to me essential to this enquiry Dr Thomson, in his elaborate and learned system of chemistry, has described six vegetable substances, which he calls mucus, jelly, sarcocol, asparagin, inulin, and ulmin He states that mucus exists in its purest form in linseed; but Vauquelin has lately shewn, that the mucilage of linseed is, in its essential characters, analogous to gum; but that it is combined with a substance similar to animal mucus: vegetable jelly, Dr Thomson himself considers as a modification of gum It is probable, from the taste of sarcocol, that it is gum combined with a little sugar Inulin is so analogous to starch, that it is probably a variety of that principle: ulmin has been lately shewn by Mr Smithson to be a compound of a peculiar extractive matter and potassa; and asparagin is probably a similar combination. If slight differences in chemical and physical properties be considered as sufficient to establish a difference in the species of vegetable substances, the catalogue of them might be enlarged to almost any extent No two compounds procured from different vegetables are precisely alike; and there are even differences in the qualities of the same compound, according to the time in which it has been collected, and the manner in which it has been prepared: the great use of classification in science is to assist the memory; and it ought to be founded upon the similarity of properties which are distinct, characteristic and invariable

The analysis of any substance containing mixtures of the different vegetable principles, may be made in such a manner as is necessary for the views of the agriculturist, with facility * A given quantity, say 200

* The increased number of vegetable proximate principles now known, and the changes to which many of them are liable during processes, and under the action of reagents, has added to the difficulty of this kind of analysis It is not often that it is required to ascertain the exact amount and proportion of every principle contained by a vegetable, neither indeed, could a few such analyses yield much information, the quantity of these principles depending so much on the circumstances under which the vegetable has been produced More frequently, however, it is necessary to ascertain the amount, or average amount, of some particular principle contained in a vegetable body. Thus in the case of substances used for feeding cattle, it is of great moment for the farmer to know their relative nutritive powers This information, however, has been more readily and satisfactorily obtained, either by ascertaining by direct experiment, how much of each substance is sufficient to maintain an adult healthy animal at a certain weight, or by determining the quantity of nitrogen contained in a given weight of the aliment; it having been ascertained that organic substances are nutritive nearly in proportion to the quantity of nitrogen they contain —See Appendix to Lecture III

In separating for use, or for ultimate analysis, proximate principles from crude vegetable substances, methods analogous to those specified in the text must be had recourse to, but as those methods must vary with the nature of every different substance, it is not easy to point out any general method of procedure.

grains, of the substance should be powdered, made into a paste, or mass, with a small quantity of water, and kneaded in the hands, or rubbed in a mortar for some time under cold water; if it contain much gluten, that principle will separate in a coherent mass. After this process, whether it has afforded gluten or not, it should be kept in contact with half a pint of cold water for three or four hours, being occasionally rubbed or agitated: the solid matter should be separated from the fluid by means of blotting paper: the fluid should be gradually heated; if any flakes appear, they are to be separated by the same means as the solid matter in the last process, *i. e.* by filtration. The fluid is then to be evaporated to dryness. The matter obtained is to be examined by applying moist paper, tinged with red cabbage juice, or violet juice, to it; if the paper become red, it contains acid matter; if it become green, alkaline matter; and the nature of the acid or alkaline matter may be known by applying the tests described page 60, 61, 62, 63. If the solid matter be sweet to the taste, it must be supposed to contain sugar; if bitterish, bitter principle, or extract; if astringent, tannin: and if it be nearly insipid, it must be principally gum or mucilage. To separate gum or mucilage from the other principles, alcohol must be boiled upon the solid matter, which will dissolve the sugar and the extract, and leave the mucilage; the weight of which may be ascertained

To separate sugar and extract, the alcohol must be evaporated till crystals begin to fall down, which are sugar; but they will generally be coloured by some extract, and can only be purified by repeated solutions in alcohol. Extract may be separated from sugar by dissolving the solid, obtained by evaporation from alcohol, in a small quantity of water, and boiling it for a long while in contact with the air. The extract will gradually fall down in the form of an insoluble powder, and the sugar will remain in solution.

If tannin exist in the first solution made by cold water, its separation is easily effected by the process described page 53. The solution of isinglass must be gradually added, to prevent the existence of an excess of animal jelly in the solution, which might be mistaken for mucilage.

When the vegetable substance, the subject of experiment, will afford no more principles to cold water, it must be exposed to boiling water. This will unite to starch if there be any, and may likewise take up more sugar, extract, and tannin, provided they be intimately combined with the other principles of the compound.

The mode of separating starch is similar to that of separating mucilage.

If after the action of hot water any thing remain, the action of boiling alcohol is then to be tried. This will dissolve resinous matter; the quantity of which may be known by evaporating the alcohol.

The last agent that may be applied is ether, which dissolves elastic gum, though the application is scarcely ever necessary; for if this principle be present, it may be easily detected by its peculiar qualities.

If any fixed oil or wax exist in the vegetable substance, it will separate during the process of boiling in water, and may be collected. Any substance not acted upon by water, alcohol, or ether, must be regarded as woody fibre.

If volatile oils exist in any vegetable substances, it is evident they may be procured, and their quantity ascertained, by distillation.

When the quantity of fixed saline, alkaline, metallic, or earthy matter, in any vegetable compound, is to be ascertained, the compound must be decomposed by heat, by exposing it, if a fixed substance, in a crucible, to

a long continued red heat; and if a volatile substance, by passing it through an ignited porcelain tube. The nature of the matter so produced, may be learned by applying the tests mentioned in page 64.

The only analyses in which the agricultural chemist can often wish to occupy himself, are those of substances containing principally starch, sugar, gluten, oils, mucilage, albumen, and tannin.

The two following statements will afford an idea of the manner in which the results of experiments may be arranged.

The first is a statement of the composition of ripe peas, deduced from experiments made by Einhof; the second are of the products afforded by oak bark, deduced from experiments conducted by myself.

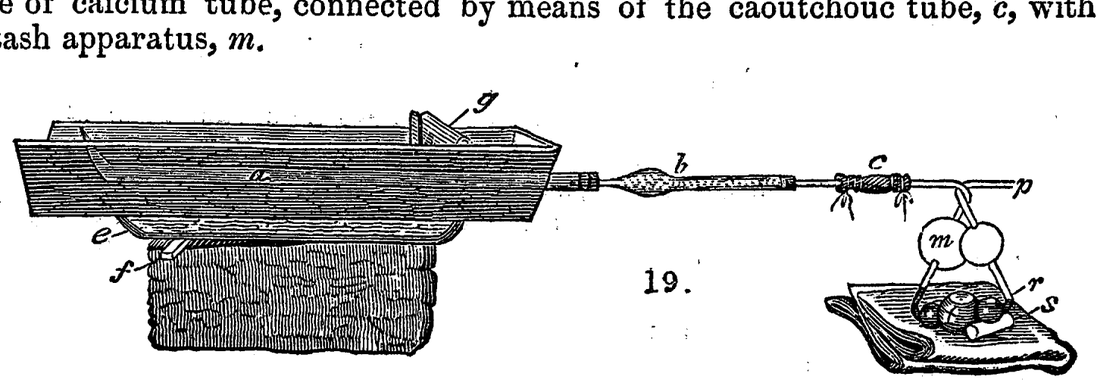
	Parts.
3840 parts of ripe peas afford, of starch	1265
Fibrous matter analogous to starch, with the coats of the peas	840
A substance analogous to gluten	550
Mucilage	249
Saccharine matter	81
Albumen	66
Volatile matter	540
Earthy phosphates	11
Loss	229

1000 parts of dry oak bark, from a small tree deprived of epidermis, contain:

Of Woody fibre	876
.. Tannin	57
.. Extract	31
.. Mucilage	18
.. Matter rendered insoluble during evaporation, probably a mixture of albumen and extract	9
.. Loss, partly saline matter	30

To ascertain the primary elements of the different vegetable principles, and the proportions in which they are combined, different methods of analysis have been adopted. The most simple are their decomposition by heat, or their formation into new products by combustion.*

* By far the most eligible method of ultimate organic analysis, is that of Liebig. It consists in heating a portion of the body to be analysed, with oxide of copper or chromate of lead, by which, if it contain no nitrogen, it is resolved into carbonic acid and water, the former of which is taken up by solution of potash, the latter by fragments of chloride of calcium, and the quantity of each is determined by weight. The apparatus used for this purpose is represented in the annexed figure; *a*, the combustion tube in its charcoal furnace, *b*, the chloride of calcium tube, connected by means of the caoutchouc tube, *c*, with the potash apparatus, *m*.



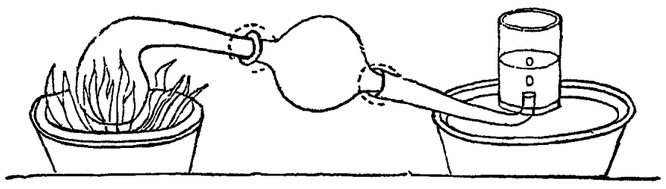
19.

The student who wishes for precise information on this important subject should

When any vegetable principle is acted on by a strong red heat, its elements become newly arranged. Such of them as are volatile are expelled in the gaseous form; and are either condensed as fluids, or remain permanently elastic. The fixed remainder is either carbonaceous, earthy, saline, alkaline, or metallic matter.

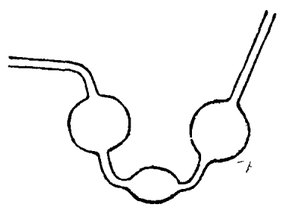
To make correct experiments on the decomposition of vegetable substances by heat, requires a complicated apparatus, much time and labour, and all the resources of the philosophical chemist; but such results as are useful to the agriculturist may be easily obtained. The apparatus necessary is a green glass retort, attached by cement to a receiver, connected with a tube passing under an inverted jar of known capacity, filled with water (Fig. 14). A given weight of the substance is to be heated to redness in the retort over a charcoal fire: the receiver is to be kept cool, and the process continued as long as any elastic matter is generated. The condensible fluids will collect in the receiver, and the fixed residuum will be found in the retort. The fluid products of the distillation of vegetable substances are principally water, with some acetous and mucous acids, and empyreumatic oil, or tar, and in some cases ammonia. The gases are carbonic acid gas, carbonic oxide, and carburetted hydrogen; sometimes with olefiant gas, and hydrogen; and sometimes, but more rarely, with azote. Carbonic acid is the only one of those gases rapidly absorbed by water; the rest are inflammable; olefiant gas burns with a bright white light; carburetted hydrogen with a light like wax; carbonic oxide with a feeble blue flame The properties of hydrogen and azote have been described in the last Lecture. The specific gravity of carbonic acid gas, is to that of air as 20·7 to 13·7 [specific gravity 1·524.—S], and it consists of one proportion of carbon 11·4, and two of oxygen 30. [CO_2 equivalent 22·12.—S.] The specific gravity of gaseous oxide of carbon, is taking the same standard 13 2 [9727.—S], and it consists of one proportion of carbon, and one of oxygen.

Fig. 14.



The specific gravities of carburetted hydrogen and olefiant gas are respectively 8 and 13 [·5594 and ·985.—S], both contain four proportions

consult "Liebig's Instructions for the Chemical Analyses of Organic Bodies, translated by Dr. Gregory." The mode of determining the nitrogen in organic bodies has been greatly improved and simplified by Varrentrapp and Will. In place of estimating the nitrogen directly, they estimate it in combination with hydrogen as ammonia. Their apparatus consists of a combustion tube of hard glass, into which is put a portion of the organic substance intimately mixed with hydrate of soda and quick-lime. The combustion tube is heated in a charcoal furnace till its contents become white and gas ceases to be evolved. The ammonia produced in this process combines with muriatic acid contained in a glass somewhat resembling the potash apparatus of Liebig: it is precipitated by chloride of platinum, dried, and weighed. The quantity of nitrogen is easily found by calculation, and a confirmation may be got from the weight of platinum found by igniting the salt. For minute details the student is referred to Varrentrapp and Will's paper in the "*Annalen der Chemie und Pharmacie*, Sept., 1841," or to a French translation of the same in the "*Annales de Chimie*"



The method of analysis by destructive distillation has been long abandoned.

of hydrogen; the first contains one proportion, the second two proportions of carbon [symbols H_2C, and $H_2 C_2$.—S].

If the weight of the carbonaceous residuum be added to the weight of the fluids condensed in the receiver, and they be subtracted from the whole weight of the substance, the remainder will be the weight of the gaseous matter.

The acetous and mucous acids, and the ammonia formed are usually in very small quantities; and by comparing the proportions of water and charcoal with the quantity of the gases, taking into account their qualities, a general idea may be formed of the composition of the substance. The proportions of the elements in the greater number of the vegetable substances which can be used as food, have been already ascertained by philosophical chemists, and have been stated in the preceding pages; the analysis by distillation may, however, in some cases, be useful in estimating the powers of manures, in a manner that will be explained in a future Lecture.

The statements of the composition of vegetable substances, quoted from MM. Gay Lussac and Thenard, were obtained by these philosophers by exposing the substances to the action of heated hyper-oxymuriate [chlorate.—S] of potassa; a body that consists of potassium, chlorine, and oxygen; and which afforded oxygen to the carbon and the hydrogen.

Their experiments were made in a peculiar apparatus, and required great caution, and were of a very delicate nature. It will not, therefore, be necessary to enter upon any details of them.

It is evident, from the whole tenor of the statements which have been made, that the most essential vegetable substances consist of hydrogen, carbon, and oxygen, in different proportions, generally alone, but in some few cases combined with azote. The acids, alkalies, earths, metallic oxides, and saline compounds, though necessary in the vegetable economy, must be considered as of less importance, particularly in their relation to agriculture, than the other principles: and as it appears from M. de Saussure's table, and from other experiments, they differ in the same species of vegetable when it is raised on different soils.

MM. Gay Lussac and Thenard have deduced three propositions, which they have called *laws* from their experiments on vegetable substances. The first is, "that a vegetable substance is always acid whenever the oxygen it contains is to the hydrogen in a greater proportion than in water."

The second, "that a vegetable substance is always resinous, or oily, or spirituous, whenever it contains oxygen in a smaller proportion to the hydrogen than exists in water."

The third, "that a vegetable substance is neither acid nor resinous; but is either saccharine or mucilaginous, or analogous to woody fibre or starch, whenever the oxygen and hydrogen in it are in the same proportions as in water."

New experiments upon other vegetable substances, besides those examined by MM. Gay Lussac and Thenard, are required before these interesting conclusions can be fully admitted.* Their researches establish, however, the close analogy between several vegetable compounds differing

* Subsequent researches have shown that these conclusions must be taken with considerable limitation. There are acids—the acetic for instance—in which the oxygen and hydrogen exist as in the neutral substances, in exact proportion to form water; there are acids in which the hydrogen is in excess, and there are acids that contain no oxygen at all. Were it necessary, other anomalies might be pointed out.

in their sensible qualities, and, combined with those of other chemists, offer simple explanations of several processes in nature and art, by which different vegetable substances are converted into each other, or changed into new compounds.

Gum and sugar afford nearly the same elements by analysis; and starch differs from them only in containing a little more carbon.* The peculiar properties of gum and sugar must depend chiefly upon the different arrangement, or degree of condensation of their elements: and it would be natural to conceive from the composition of these bodies, as well as that of starch, that all three would be easily convertible one into the other; which is actually the case.

At the time of the ripening of corn, the saccharine matter in the grain, and that carried from the sap vessels into the grain, becomes coagulated, and forms starch. And in the process of malting, the converse change occurs. The starch of grain is converted into sugar. As there is a little absorption of oxygen, and a formation of carbonic acid in this case, it is probable that the starch loses a little carbon, which combines with the oxygen to form carbonic acid; and probably the oxygen tends to acidify the gluten of the grain, and thus breaks down the texture of the starch, gives a new arrangement to its elements, and renders it soluble in water.

Mr Cruikshank, by exposing syrup to a substance named phosphuret of lime, which has a great tendency to decompose water, converted a part of the sugar into a matter analogous to mucilage. And M. Kirchhoff, recently, has converted starch into sugar by a very simple process, that of boiling in very diluted sulphuric acid. The proportions are 100 parts of starch, 400 parts of water, and 1 part of sulphuric acid by weight. This mixture is to be kept boiling for 40 hours; the loss of water by evaporation being supplied by new quantities. The acid is to be neutralized by lime; and the sugar crystallised by cooling. This experiment has been tried with success by many persons. Dr Tuthill, from a pound and a half of potatoe starch, procured a pound and a quarter of crystalline brown sugar, which he conceives possessed properties intermediate between cane sugar and grape sugar.†

It is probable that the conversion of starch into sugar is effected merely by the attraction of the acid for the elements of sugar; for various experiments have been made, which prove that the acid is not decomposed, and that no elastic matter is set free: probably the colour of the sugar is owing to the disengagement, or new combination of a little carbon, the slight excess of which, as has been just stated, constitutes the only difference perceptible by analysis between sugar and starch.

M. Bouillon la Grange, by slightly roasting starch, has rendered it soluble in cold water; and the solution evaporated afforded a substance, having the characters of mucilage.

Gluten and albumen differ from the other vegetable products, principally by containing azote. When gluten is kept long in water it undergoes fermentation; ammonia (which contains its azote) is given off with acetic acid: and a fatty matter, and a substance analogous to woody fibre remain.

* The formulæ representing these substances have been already given. The reader will remember that they are

Grape Sugar	$C_{12} H_{14} O_{14}$
Gum	$C_{12} H_{11} O_{11}$
Starch	$C_{12} H_{10} O_{10}$

† It has been ascertained that it is grape sugar that is produced.

Extract, tannin and gallic acid, when their solutions are long exposed to air, deposit a matter similar to woody fibre, and the solid substances are rendered analogous to woody fibre by slight roasting; and in these cases it is probable that part of their oxygen and hydrogen is separated as water.

All the other vegetable principles differ from the vegetable acids in containing more hydrogen and carbon, or less oxygen: many of them, therefore, are easily converted into vegetable acids by a mere subtraction of some proportions of hydrogen. The vegetable acids, for the most part, are convertible into each other by easy processes. The oxalic contains most oxygen; the acetic the least: and this last substance is easily formed by the distillation of other vegetable substances, or by the action of the atmosphere on such of them as are soluble in water; probably by the mere combination of oxygen with hydrogen and carbon, or in some cases by the subtraction of a portion of hydrogen.

Alcohol, or spirits of wine, has been often mentioned in the course of these Lectures. This substance was not described amongst the vegetable principles, because it has never been found ready formed in the organs of plants. It is procured by a change in the principles of saccharine matter, in a process called vinous fermentation.

The expressed juice of the grape contains sugar, mucilage, gluten and some saline matter, principally composed of tartaric acid: when this juice, or *must*, as it is commonly called, is exposed to the temperature of about 70°, the fermentation begins; it becomes thick and turbid; its temperature increases, and carbonic acid gas is disengaged in abundance. In a few days the fermentation ceases; the solid matter that rendered the juice turbid falls to the bottom, and it clears; the sweet taste of the fluid is in a great measure destroyed, and it is become spirituous.

Fabroni has shewn that the gluten in *must* is essential to fermentation; and that chemist has made saccharine matter ferment, by adding to its solution in water, common vegetable gluten and tartaric acid. Gay Lussac has demonstrated that *must* will not ferment when freed from air by boiling, and placed out of the contact of oxygen; but that fermentation begins as soon as it is exposed to the oxygen of air, a little of that principle being absorbed; and that it then continues independent of the presence of the atmosphere.

In the manufacture of ale and porter, the sugar formed during the germination of barley is made to ferment by dissolving it in water with a little yeast, which contains gluten in the state proper for producing fermentation, and exposing it to the requisite temperature: carbonic acid gas is given off as in the fermentation of *must*, and the liquor gradually becomes spirituous.

Similar phenomena occur in the fermentation of the sugar in the juice of apples, and other ripe fruits. It appears that fermentation depends entirely upon a new arrangement of the elements of sugar; part of the carbon uniting to oxygen to form carbonic acid, and the remaining carbon, hydrogen, and oxygen combining as alcohol; and the use of the gluten or yeast, and the primary exposure to air seems to be to occasion the formation of a certain quantity of carbonic acid; and this change being once produced is continued; its agency may be compared to that of a spark in producing the inflammation of gunpowder; the increase of temperature occasioned by the formation of one quantity of carbonic acid occasions the combination of the elements of another quantity. *

* Liebig has shown that *ferment* is an azotized substance undergoing putrefac-

The results obtained by different chemists in experiments on the analysis of alcohol differ so much, that no general conclusions can be drawn from them. If it be supposed that one proportion of carbonic acid is formed in the fermentation of sugar; then according to Dr. Thomson's analysis of sugar, which gives its composition as 3 proportions of carbon, 4 of oxygen, and 8 of hydrogen, alcohol would consist of 2 proportions of carbon, 2 of oxygen, and 8 of hydrogen; and it might be considered as containing the same elements as two proportions of olefiant gas, with two proportions of oxygen.*

Alcohol in its purest known form, is a highly inflammable liquid, of specific gravity 796, at the temperature of 60°; it boils at about 170° Fahrenheit. This alcohol is obtained by repeated distillation of the strongest common spirit from the salt called by chemists muriate of lime, it having been previously heated red hot.

The strongest alcohol obtained by the distillation of spirit without salts, has seldom a less specific gravity than ·825 at 60°; and it contains, according to Lowitz's experiments, 89 parts of the alcohol of ·796, and 11 parts of water. The spirit established as *proof spirit* by act of parliament passed

tion and decay. When this substance is added to a solution of sugar at a proper temperature, it gradually unites with oxygen and becomes insoluble. While this action is going on, the sugar undergoes a simultaneous transformation, being converted into carbonic acid and alcohol. If an insufficient quantity of ferment has been added, there remains when all the ferment has undergone its change, a quantity of sugar in solution which cannot undergo transformation till a fresh supply of ferment is added. If an overdose of ferment has been used, a quantity of it remains in solution after all the sugar has been changed into alcohol, which, by promoting the absorption of oxygen, converts the alcohol into acetic acid, unless the air is excluded.

Other azotized substances both of animal and vegetable origin, are capable of acting as ferments on saccharine solutions, and those vegetable juices which naturally contain azotized matters are consequently capable of spontaneous fermentation. A solution of pure sugar is incapable of this change, and requires some ferment to be added to it.

* The composition of alcohol is now well understood. It is represented by the empirical formula $C_4 H_6 O_2$ and by the rational formula $AeO+HO$. That is to say, it is regarded as the hydrated oxide of *ethule* ($C_4 H_5$) which in the rational formula is represented by the symbol Ae.

With respect to the theory of its formation from sugar,

1 Equivalent of crystallized grape sugar,	C_{12}	H_{14}	O_{14}	is resolved into
2 Equivalents of water		H_2	O_2	
2 Equivalents of alcohol	C_8	H_{12}	O_4	
4 Equivalents of carbonic acid	C_4		O_8	
	C_{12}	H_{14}	O_{14}.	

Crystallised cane sugar, it will be remembered, contains three equivalents less of water and its elements than grape sugar, or one equivalent less than grape sugar which has been dried at the temperature of boiling water; an additional equivalent of water must therefore take part in the transformation of cane sugar into carbonic acid and alcohol, hence

1 Equivalent of cane sugar	C_{12}	H_{11}	O_{11}	yield	2 Equivalents alcohol	C_8	H_{12} O_4
					and		
and 1 Equivalent of water		H	O		4 Equivalents carbonic acid	C_4	O_8
	C_{12}	H_{12}	O_{12}			C_{12}	H_{12} O_{12}

Thus cane sugar would appear to be first converted into grape sugar and then into carbonic acid and alcohol.

in 1762, ought to have the specific gravity of ·916; and this contains nearly equal weights of pure alcohol and water.

The alcohol in fermented liquors is in combination with water, colouring matter, sugar, mucilage, and the vegetable acids. It has been often doubted whether it can be procured by any other process than distillation; and some persons have even supposed that it *is formed* by distillation. The recent experiments of Mr. Brande are conclusive against both these opinions. That gentleman has shewn that the colouring and acid matter in wines may be, for the most part, separated in a solid form by the action of a solution of sugar of lead (acetate of lead), and that the alcohol may be then obtained by abstracting the water by means of hydrate of potassa or muriate of lime, without artificial heat.

The intoxicating powers of fermented liquors depend on the alcohol that they contain; but their action on the stomach is modified by the acid, saccharine, or mucilaginous substances they hold in solution. Alcohol probably acts with most efficacy when it is most loosely combined; and its energy seems to be impaired by union with large quantities of water, or with sugar, or acid, or extractive matter.

The following table contains the results of Mr. Brande's experiments on the quantity of alcohol of ·825 at 60°, in different fermented liquors.*

* The following table from Dr. Christison's Dispensatory, contains the most recent estimate of alcohol in wines.

WINES EXAMINED.	Alcohol by weight in 100 parts.	Proof Spirit by volume in 100 parts.
Port, weakest,	14·94	30·56
mean of 7 wines,	16·20	33·91
strongest,	17·10	37·27
White Port,	14·97	31·31
Sherry, weakest,	13·98	30·84
mean of 13 wines not long in cask,	15·37	33·59
strongest,	16·17	35·12
mean of 9, long in cask, East Indies,	14·72	32·30
Madre da Xeres,	16·90	37·06
Madeira, long in cask in the East Indies,	14·09	30·80
strongest,	16·90	37·00
Tenneriffe, long in cask at Calcutta,	13·84	30·21
Sercial,	15·45	33·65
Dry Lisbon,	16·14	34·71
Shiraz,	12·95	28·30
Ammontillado,	12·63	27·60
Claret, 1st growth 1811,	7·72	16·95
Chateau Latour, Do. 1825	7·78	17·06
Rosan, 2d growth 1825,	7·61	16·74
Vin Ordinaire, Bordeaux,	8·99	18·96
Rives Altes,	9·31	22·35
Malmsey,	12·86	28·37
Rudesheimer, first quality,	8·40	18·44
Do. inferior,	6·90	15·19
Hambacher, first quality,	7·35	16·15
Edinburgh Ale, unbottled,	5·70	12·60
Same Ale, two years in bottle,	6·06	13·40
London Porter, four months in bottle,	5·36	11·91

Wine.	Proportion of Alcohol, per Cent by Measure.	Wine.	Proportion of Alcohol, per Cent by Measure.
Port	21·40	White Hermitage	17·43
Do.	22·30	Red Hermitage	12·32
Do.	23·39	Hock	14·37
Do.	23·71	Do.	8·88
Do.	24·29	Vin de Grave	12·80
Do.	25·83	Frontignac	12·79
Madeira	19·24	Coti Roti	12·32
Do.	21·40	Rousillon	17·26
Do.	23·93	Cape Madeira	18·11
Do.	24·42	Cape Muschat	18·25
Sherry	18·25	Constantia	19·75
Do.	18·79	Tent	13·30
Do.	19·81	Sheraaz	15·52
Do.	19·83	Syracuse	15·28
Claret	12·91	Nice	14·63
Do.	14·08	Tokay	9·88
Do.	16·32	Raisin Wine	25·77
Calcavella	18·10	Grape Wine	18·11
Lisbon	18·94	Currant Wine	20·55
Malaga	17·26	Gooseberry Wine	11·84
Bucellas	18·49	Elder Wine	8·79
Red Madeira	18·40	Cyder	9·87
Malmsey Madeira	16·40	Perry	7·26
Marsala	25·09	Brown Stout	6·80
Do.	17·26	Ale	8·88
Red Champagne	11·30	Brandy	53·39
White Champagne	12·80	Rum	53·68
Burgundy	14·53	Hollands	51·60
Do.	11·95		

The spirits distilled from different fermented liquors differ in their flavour: for peculiar odorous matter, or volatile oils, rise in most cases with the alcohol. The spirit from malt usually has an empyreumatic taste like that of the oil formed by the distillation of vegetable substances. The best brandies seem to owe their flavour to a peculiar oily matter, formed probably by the action of the tartaric acid on alcohol; and rum derives its characteristic taste from a principle in the sugar cane. All the common spirits may, I find, be deprived of their peculiar flavour by repeatedly digesting them with a mixture of well burnt charcoal and quicklime; they then afford pure alcohol by distillation. The cogniac brandies, I find, contain vegetable prussic acid, and their flavour may be imitated by adding to a solution of alcohol in water of the same strength, a few drops of the ethereal oil of wine produced during the formation of ether,* and a similar quantity of vegetable prussic acid procured from laurel leaves or any bitter kernels.

I have mentioned *ether* in the course of this lecture; this substance is procured from alcohol by distilling a mixture of equal parts of alcohol and sulphuric acid. It is the lightest known liquid substance, being of specific

* In the process of the distillation of alcohol and sulphuric acid after the ether is procured; by a higher degree of heat, a yellow fluid is produced, which is the substance in question. It has a fragrant smell and an agreeable taste.—D.

gravity ·632 at 60°. [Specific gravity 0·7237 at 55° F.] It is very volatile and rises in vapour even by the heat of the body. It is highly inflammable. In the formation of ether it is most probable that carbon and the elements of water are separated from the alcohol, and that ether differs from alcohol in containing less oxygen and carbon; but its composition has not yet been accurately ascertained.* Like alcohol it possesses intoxicating powers.

A number of the changes taking place in the vegetable principles depend upon the separation of oxygen and hydrogen as water from the compound; but there is one of very great importance, in which a new combination of the elements of water is the principal operation. This is in the manufacture of bread. When any kind of flour, which consists principally of starch, is made into a paste with water, and immediately and gradually heated to about 440°, it increases in weight, and is found entirely altered in its properties; it has lost its solubility in water, and its power of being converted into sugar. In this state it is unleavened bread.

When the flour of corn or the starch of potatoes, mixed with boiled potatoes, is made into a paste with water, kept warm, and suffered to remain 30 or 40 hours, it ferments, carbonic acid gas is disengaged from it, and it becomes filled with globules of elastic fluid. In this state it is raised dough, and affords by baking, leavened bread; but this bread is sour and disagreeable to the taste; and leavened bread for use is made by mixing a little dough, that has fermented, with new dough, and kneading them together, or by kneading the bread with a small quantity of yeast.

In the formation of wheaten bread more than $\frac{1}{4}$ of the elements of water combine with the flour; more water is consolidated in the formation of bread from barley, and still more in that from oats; but the gluten in wheat, being in much larger quantity than in other grain seems to form a combination with the starch and water, which renders wheaten bread more digestible than the other species of bread.

The arrangement of many of the vegetable principles in the different parts of plants has been incidentally mentioned in this lecture; but a more particular statement is required to afford just views of the relation between their organization and chemical constitution, which is an object of great importance. The tubes and hexagonal cells in the vascular system of plants are composed of woody fibre; and when they are not filled with fluid matter they contain some of the solid materials which formed a constituent part of the fluids belonging to them.

In the roots, trunk, and branches, the bark, alburnum, and heartwood, the leaves and flowers; the great basis of the solid parts is woody fibre. It forms by far the greatest part of the heart-wood and bark; there is less in the alburnum, and still less in the leaves and flowers. The alburnum of the birch contains so much sugar and mucilage, that it is sometimes used in the North of Europe as a substitute for bread. The leaves of the cabbage, broccoli, and sea-cale, contain much mucilage, a little saccharine matter, and a little albumen. From 1000 parts of the leaves of common cabbage I obtained 41 parts of mucilage, 24 of sugar, and 8 of albuminous matter.

In bulbous roots, and sometimes in common roots, a large quantity of

* Ether is represented by the empirical formula $C_4 H_5 O$. It is regarded as the oxide of *ethule* ($C_4 H_5$), and if this radical is represented by the symbol Ae, the rational formula representing ether will be AeO.

starch, albumen, and mucilage, are often found deposited in the vessels; and they are most abundant after the sap has ceased to flow; and afford a nourishment for the early shoots made in spring. The potatoe is the bulb that contains the largest quantity of soluble matter in its cells and vessels; and it is of most importance in its application as food. Potatoes in general afford from $\frac{1}{5}$ to $\frac{1}{7}$ their weight of dry starch. From 100 parts of the common *Kidney potatoe*, Dr. Pearson obtained from 32 to 28 parts of meal, which contained from 23 to 20 of starch and mucilage: and 100 parts of the *Apple potatoe* in various experiments, afforded me from 18 to 20 parts of pure starch. From 5 pounds of the variety of the potatoe called *Captain hart*, Mr. Skrimshire, jun. obtained 12 oz. of starch, from the same quantity of the *Rough red* potatoe $10\frac{1}{2}$ oz., from the *Moulton white* $11\frac{3}{4}$, from the *Yorkshire kidney* $10\frac{3}{4}$ oz., from *Hundred eyes* 9 oz., from *Purple red* $8\frac{1}{2}$, from *Ox noble* $8\frac{1}{4}$. The other soluble substances in the potatoe are albumen and mucilage.

From the analyses of Einhoff it appears that 7680 parts of potatoes afford:

Of Starch	1153
.. Fibrous matter analogous to starch .	540
.. Albumen	107
.. Mucilage in the state of a saturated solution	312
	2112

so that a fourth part of the weight of the potatoe at least may be considered as nutritive matter.

The turnip, carrot and parsnip, afford principally saccharine, mucilaginous, and extractive matter. I obtained from 1000 parts of common turnips 7 parts of mucilage, 34 of saccharine matter, and nearly 1 part of albumen. 1000 parts of carrots furnished 95 parts of sugar, 3 parts of mucilage, and $\frac{1}{2}$ part of extract; 1000 parts of parsnip afforded 90 parts of saccharine matter, and 9 parts of mucilage. The *Walcheren* or *white carrot*, gave in 1000 parts, 98 parts of sugar, 2 parts of mucilage, and 1 of extract.

Fruits, in the organization of their soft parts, approach to the nature of bulbs. They contain a certain quantity of nourishment laid up in their cells for the use of the embryon plant; mucilage, sugar, and starch, are found in many of them, often combined with vegetable acids. Most of the fruit trees common in Britain have been naturalized on account of the saccharine matter they contain, which, united to the vegetable acids and mucilage, renders them at once agreeable to the taste and nutritive.

The value of fruits for the manufacture of fermented liquors may be judged of from the specific gravity of their expressed juices. The best cyder and perry are made from those apples and pears that afford the densest juices; and a comparison between different fruits may be made with tolerable accuracy by plunging them together into a saturated solution of salt, or a strong solution of sugar; those that sink deepest will afford the richest juice.

Starch, or coagulated mucilage, forms the greatest part of the seeds and grains used for food; and they are generally combined with gluten, oil, or albuminous matter. In corn, with gluten, in peas and beans, with albuminous matter, and in rape-seed, hemp-seed, linseed, and the kernels of most nuts, with oils.

I found 100 parts of good full-grained wheat sown in autumn to afford:

Of Starch	77
.. Gluten	19

100 parts of wheat sown in spring:

Of Starch	70
.. Gluten	24

100 parts of Barbary wheat:

Of Starch	74
.. Gluten	23

100 parts of Sicilian wheat:

Of Starch	75
.. Gluten	21

I have examined different specimens of North American wheat, all of them have contained rather more gluten than the British. In general the wheat of warm climates abounds more in gluten, and in insoluble parts; and it is of greater specific gravity, harder and more difficult to grind.

The wheat of the south of Europe, in consequence of the larger quantity of gluten it contains, is peculiarly fitted for making macaroni, and other preparations of flour in which a glutinous quality is considered as an excellence.

In some experiments made on barley, I obtained from 100 parts of full and fair Norfolk barley:

Of Starch	79
.. Gluten	6
.. Husk	8

The remaining 7 parts saccharine matter.

Einhoff has published a minute analysis of barley-meal. He found in 3840 parts:

Of volatile matter	360
.. Albumen	44
.. Saccharine matter	200
.. Mucilage	176
.. Phosphate of lime, with some albumen	9
.. Gluten	135
.. Husk, with some gluten and starch	260
.. Starch not quite free from gluten	2580
.. Loss	78

Rye afforded to Einhoff, in 3840 parts; 2520 meal, 930 husk, and 390 moisture; and the same quantity of meal analysed gave:

Of Starch	2345
.. Albumen	126
.. Mucilage	426
.. Saccharine matter	126
.. Gluten not dried	364

Remainder husk and loss.

I obtained from 1000 parts of rye, grown in Suffolk, 61 parts of starch, and 5 parts of gluten.

100 parts of oats, from Sussex afforded me 59 parts of starch, 6 of gluten, and 2 of saccharine matter.

1000 parts of peas, grown in Norfolk, afforded me 501 parts of starch, 22 parts of saccharine matter, 35 parts of albuminous matter, and 16 parts of extract, which became insoluble during evaporation of the saccharine fluid.

From 3840 parts of marsh beans *(Vicia faba)*, Einhoff obtained:

Of Starch	1312
.. Albumen	31
.. Other matters which may be conceived nutritive; such as gummy, starchy, fibrous matter, analogous to animal matter	1204

The same quantity of kidney beans *(Phaseolus Vulgaris)*, afforded:

Of matter analogous to starch	1805
.. Albumen and matter approaching to animal matter in its nature	851
.. Mucilage	799

From 3840 parts of lentiles he obtained 1260 parts of starch, and 1433 of a matter analogous to animal matter.

The matter analogous to animal matter is described by Einhoff as a glutinous substance insoluble in water; soluble in alcohol when dry, having the appearance of glue; probably a peculiar modification of gluten.

From 16 parts of hemp-seeds Bucholz obtained 3 parts of oil, $3\frac{1}{2}$ parts of albumen, about $1\frac{3}{4}$ of saccharine and gummy matter. The insoluble husks and coats of the seeds weighed $6\frac{1}{8}$ parts.

The different parts of flowers contain different substances: the pollen, or impregnating dust of the date, has been found by Fourcroy and Vauquelin to contain a matter analogous to gluten, and a soluble extract abounding in malic acid. Link found in the pollen of the hazel tree, much tannin and gluten.

Saccharine matter is found in the nectarium of flowers, or the receptacles within the corolla, and by tempting the larger insects into the flowers, it renders the work of impregnation more secure; for the pollen is often by their means applied to the stigma; and this is particularly the case when the male and female organs are in different flowers or different plants.

It has been stated that the fragrance of flowers depends upon the volatile oils they contain; and these oils, by their constant evaporation, surround the flower with a kind of odorous atmosphere; which, at the same time that it entices larger insects, may probably preserve the parts of fructification from the ravages of smaller ones. Volatile oils, or odorous substances, seem particularly destructive to these minute insects and animalcules which feed on the substance of vegetables; thousands of aphides may be usually seen in the stalk and leaves of the rose; but none of them are ever observed on the flower. Camphor is used to preserve the collections of naturalists. The woods that contain aromatic oils are remarked for their indestructibility; and for their exemption from the attacks of insects; this is particularly the case with the cedar, rose-wood, and cypress. The gates of Constantinople, which were made of this last wood, stood entire from the time of Constantine, their founder, to that of Pope Eugene IV., a period of 1,100 years.

The petals of many flowers afford saccharine and mucilaginous matter. The white lily yields mucilage abundantly; and the orange lily a mixture of mucilage and sugar; the petals of the convolvulus afford sugar, mucilage, and albuminous matter.

The chemical nature of the colouring matters of flowers has not as yet been subjected to any very accurate observation. These colouring matters, in general, are very transient, particularly the blues and reds; alkalies change the colours of most flowers to green and acids to red. An imita-

tion of the colouring matter may be made by digesting solutions of gall-nuts with chalk; a green fluid is obtained, which becomes red by the action of an acid; and has its green colour restored by means of alkalies.

The yellow colouring matters of flowers are the most permanent; the carthamus contains a red and a yellow colouring matter;* the yellow colouring matter is easily dissolved by water, and from the red, rouge is prepared from a process which is kept secret.

The same substances as exist in the solid parts of plants are found in their fluids, with the exception of woody fibre. Fixed and volatile oils containing resin or camphor, or analogous substances in solution, exist in the cylindrical tubes belonging to a number of plants. Different species of Euphorbia emit a milky juice, which, when exposed to air, deposits a substance analogous to starch, and another similar to gluten.

Opium, gum elastic, gamboge, the poisons of the *Upas Antiar* and *Tieute*, and other substances that exude from plants, may be considered as peculiar juices belonging to appropriate vessels.

The sap of plants, in general, is very compound in its nature; and contains most saccharine, mucilaginous, and albuminous matter in the alburnum; and most tannin and extract in the bark. The cambium, which is the mucilaginous fluid found in trees between the wood and the bark, and which is essential to the formation of new parts, seems to be derived from these two kinds of sap; and probably is a combination of the mucilaginous and albuminous matter of the one, with the astringent matter of the other, in a state fitted to become organized by the separation of its watery parts.

The alburnous saps of some trees have been chemically examined by Vauquelin. He found in those of the elm, beech, yoke-elm, hornbeam and birch, extractive and mucilaginous matter, acetic acid combined with potassa or lime. The solid matter afforded by their evaporation yielded an ammoniacal smell, probably owing to albumen; the sap of the birch afforded saccharine matter.

Deyeux in the sap of the vine and the yoke-elm has detected a matter analogous to the curd of milk. I found a substance similar to albumen in the sap of the walnut tree.

I found the juice which exudes from the vessels of the marsh-mallow when cut, to be a solution of mucilage.

The fluids contained in the sap vessels of wheat and barley, afforded in some experiments which I made on them, mucilage, sugar, and a matter which coagulated by heat; which last was most abundant in wheat.

The following table contains a statement of the quantity of soluble or nutritive matters contained in varieties of the different substances that have been mentioned, and of some others which are used as articles of food, either for man or for cattle. The analyses are my own, and were conducted with a view to a knowledge of the general nature and quantity of the products, and not of their intimate chemical composition. The soluble matters afforded by the grasses, except that from the fiorin in winter, were obtained by Mr Sinclair, gardener to the Duke of Bedford, from given weights of the grasses cut when the seeds were ripe; they were sent to me, by his Grace's desire, for chemical examination; and form part of the results of an important and extensive series of experiments on grasses, made by direction of the Duke, at Woburn Abbey, the full details of which I shall hereafter have the pleasure of stating.

* Vegetable physiologists consider that there are two types of colour in monochromatic flowers, namely yellow and blue. Plants belonging to each of these types have a certain range of colours into which they may lapse thus the milk-

TABLE

Of the Quantities of Soluble or Nutritive Matters afforded by 1000 *Parts of different Vegetable Substances.*

Vegetables or Vegetable Substance.	Whole quantity of Soluble or Nutritive Matter	Mucilage or Starch.	Saccharine Matter or Sugar.	Gluten or Albumen.	Extract, or Matter rendered Insoluble during Evaporation.
Middlesex wheat, average crop,	955	765	...	190	
Spring wheat, - -	940	700	...	240	
Mildewed wheat of 1806,	210	178	...	32	
Blighted wheat of 1804,	650	520	...	130	
Thick-skinned Sicilian wheat of 1810, - - -	955	725	...	230	
Thin-skinned Sicilian wheat of 1810, - - -	961	722	..	239	
Wheat from Poland, -	950	750	...	200	
North American Wheat,	955	730	...	225	
Norfolk barley, - -	920	790	70	60	
Oats from Scotland, -	743	641	15	87	
Rye from Yorkshire, -	792	645	38	109	
Common bean, - -	570	426	...	103	41
Dry peas, - - -	574	501	22	35	16
Potatoes, - - -	from 260 to 200	from 200 to 155	from 20 to 15	from 40 to 30	
Linseeed cake, - -	151	123	11	17	
Red beet, - - -	148	14	121	13	
White beet, - - -	136	13	119	4	
Parsnip, - - -	99	9	90	..	
Carrots, - - -	98	3	95	...	
Common turnips, - -	42	7	34	1	
Swedish turnips, - -	64	9	51	2	2
Cabbage, - - -	73	41	24	8	
Broad-leaved clover, -	39	31	3	2	3
Long-rooted clover, -	39	30	4	3	2
White clover, - -	32	29	1	3	5
Sainfoin, - - -	39	28	2	3	6
Lucerne, - - -	23	18	1	...	4
Meadow fox-tail grass, -	33	24	3	...	6
Perennial rye grass, -	39	26	4	...	5
Fertile meadow grass, -	78	65	6	...	7
Roughish meadow grass, -	39	29	5	...	6
Crested dog's-tail grass, -	35	28	3	...	4
Spiked fescue grass, -	19	15	2	...	2
Sweet-scented soft grass, -	82	72	4	...	6
Sweet-scented vernal grass,	50	43	4	...	3
Fiorin, - - - -	54	46	5	1	2
Fiorin cut in winter, -	76	64	8	1	3

wort, (*Polygala vulgaris*), which belongs to the blue or *cyanic* type, may be found blue, pink, red or white, but never yellow, and the Rose which belongs to the *zanthic* type may occur red, yellow or white, but not blue. There are exceptions, particularly among cultivated plants, and the law does not apply to polychromatic flowers, for the Pansy, (*Viola tricolor*), even in its wild state, has both yellow and blue in the petals of the same flower.

All these substances were submitted to experiment green, and in their natural states. It is probable that the excellence of the different articles as food will be found to be in a great measure proportional to the quantities of soluble or nutritive matters they afford; but still these quantities cannot be regarded as *absolutely* denoting their value. Albuminous or glutinous matters have the characters of animal substances; sugar is more nourishing, and extractive matter less nourishing, than any other principles composed of carbon, hydrogen, and oxygen. Certain combinations likewise of these substances may be more nutritive than others.

I have been informed by Sir Joseph Banks, that the Derbyshire miners in winter, prefer oat cakes to wheaten bread; finding that this kind of nourishment enables them to support their strength and perform their labour better. In summer, they say oat cake heats them, and they then consume the finest wheaten bread they can procure. Even the skin of the kernel of oats probably has a nourishing power, and is rendered partly soluble in the stomach with the starch and gluten. In most countries of Europe, except Britain, and in Arabia, horses are fed with barley mixed with chopped straw; and the chopped straw seems to act the same part as the husk of the oat. In the mill 14 lbs. of good wheat yield on an average 13 lbs. of flour; the same quantity of barley 12 lbs., and of oats only 8 lbs.*

In the south of Europe, hard or thin-skinned wheat is in higher estimation, than soft or thick-skinned wheat: the reason of which is obvious, from the larger quantity of gluten and nutritive matter it contains. I have made an analysis of only one specimen of thin-skinned wheat, so that other specimens may possibly contain more nutritive matter than that in the Table: the Barbary and Sicilian wheats, before referred to, were thick-skinned wheats. In England the difficulty of grinding thin-skinned wheat is an objection; but this difficulty is easily overcome by moistening the corn.†

* The smaller proportion of meal yielded by oats is owing to several causes. The husk is proportionally thicker and heavier, the dark coloured coat of the groats requires to be removed, and as the husk is not so closely adherent as in barley, it is capable of removal after kiln-drying. The loss, therefore, consists of husk, of what is called by millers *dust*, and of evaporated water. The husk is not entirely removed in the process of shelling, but what remains after sifting, by no means compensates for the loss in drying. In different varieties of oat the ratio of the weight of groats to that of husk varies considerably. In the course of many trials I have found the husk vary from 20 to 25 per cent. of the weight of the grain as sent to the mill.

† For the following note on this subject I am indebted to the kindness of the Right Hon. Sir Joseph Banks, Bart. K. B.—D.

Information received from John Jeffery, Esq. His Majesty's Consul General at Lisbon, in answer to Queries transmitted to him, from the Comm. of P. C. for Trade, dated Jan. 12, 1812.

To grind hard corn with the mill-stones used in England, the wheat must be well screened, then sprinkled with water at the miller's discretion, and laid in heaps and frequently turned and thoroughly mixed, which will soften the husk so as to make it separate from the flour in grinding, and of course give the flour a brighter colour; otherwise the flinty quality of the wheat, and the thinness of the skin will prevent its separation, and will render the flour unfit for making into bread.

I am informed by a miller of considerable experience, and who works his mills entirely with the stones from England or Ireland, that he frequently prepares the hard Barbary corn by immersing it in water in close wicker baskets, and spreading it thinly on a floor to dry; much depends on the judgment and

skill of the miller in preparing the corn for the mill according to its relative quality. I beg to observe, that it is not from this previous process of wetting the corn that the weight in the flour of hard corn is encreased; but from its natural quality it imbibes considerably more water in making it into bread. The mill-stones must not be cut too deep, but the furrows very fine, and picked in the usual way. The mills should work with less velocity in grinding hard corn than with soft, and set to work at first with soft corn, till the mill ceases to work well; then put on the hard corn. Hard wheat always sells at a higher price in the market than soft wheat, on an average of ten to fifteen per cent.; as it produces more flour in proportion, and less bran than the soft corn.

Flour made from hard wheat is more esteemed than what is made from soft corn; and both sorts are applied to every purpose.

The flour of hard wheat is in general superior to that made from soft; and there is no difference in the process of making them into bread; but the flour from hard wheat will imbibe and retain more water in making into bread; and will consequently produce more weight of bread: it is the practice here, and which I am persuaded it would be adviseable to adopt in England, to make bread with flour of hard and soft wheat, which by being mixed, will make the bread much better.

(Signed) JOHN JEFFERY.

APPENDIX TO LECTURE III.

[BY THE EDITOR.]

It was stated in a note, page 67, that it has been established by recent researches, that different substances used as aliments are nutritive nearly in proportion to the nitrogen they contain. This fact is clearly made out in the following Table, translated from BOUSSINGAULT—*Annales de Chimie*, Nov. 1836. It merits the attention of every Stock Farmer.

The first three columns require no explanation. The fourth, entitled "*Theoretical Equivalents*," shews the weight of each aliment, which is equivalent to, or can replace 100 parts of good hay. The numbers in this column are calculated from the quantity of nitrogen contained by the substances in their normal state, and the chief interest of the Table is in the comparison of the numbers thus found with those in the fifth column, entitled "*Practical Equivalents*." These practical equivalents indicate the weight of each aliment required to maintain an adult healthy animal for a given time at a uniform weight, the same standard being adopted as in the fourth column :—

SUBSTANCES.	Percentage of Water lost in drying at 212° F.	Percentage of Nitrogen in the dried Substances.	Percentage of Nitrogen in the Substances not dried.	Theoretical Equivalents.	Practical Equivalents.	Authors who have given the Practical Equivalents.*
Common Hay, .	11·2	1.18	1·04	100	100	
Hay of red clover cut in flower, .	16·6	2·77	1·76	60	90	Thaer.
Clover, green, .	...	...	0·50	208	...	
Lucerne hay, .	16·6	1·66	1·38	75	90	Thaer.
Do. green, .	...	...	0·38	347	...	
Vetch halm dried,	11·0	1·57	1·41	74	83	
Wheat straw, .	19·3	0·30	0·20	520	400	Thaer.
Rye straw, .	12·2	0·20	0·17	611	400	
Oat straw, .	21·0	0·36	0·19	547	400	
Barley straw, .	11·0	0·26	0·20	520	400	
Potatoes, . .	92·3	1·80	0·37	281	200	
Jerusalem Artichokes,	75·5	2·20	0·42	248	205	Block.
Cabbages, hearted,	92·3	3·70	0·28	371	429	Thaer.
Carrots, . .	87·6	2·40	0·30	347	319	Th. 300 M. 338.
Mangold-wurzel,	90·5	2·70	0·26	400	397	Th. and En. 460. Sch. 333.
Turnips, . .	91·8	2·20	0·17	612	607	Th. 455 En. 526. M. 800. Mr. 667. Mean 612.
Beans, . .	7·9	5·50	5·11	20	...	
Peas, yellow, .	16·7	4·08	3·40	31	30	Block.
French beans, white,	5·0	4·30	4·08	25	...	
Lentils, . .	9·0	4·40	4·00	26	...	
Vetches, . .	14·6	5·13	4·37	24	...	
Rape cake, .	10·5	5·50	4·92	21	...	
Maize, . .	18·0	2·00	1·64	63	59	Block.
Buckwheat, .	12·5	2·40	2·10	50	...	
Wheat, . .	10·5	2·38	2·13	49	27	Block.
Rye, . .	11·0	2·29	2·04	51	33	Block.
Barley, . .	13·2	2·02	1·76	59	54	En. 69, Bl. 33, Mean 51.
Oats, . .	12·4	2·22	1·92	54	61	En. 83, Bl. 39.
Wheat flour, .	12·3	2·60	2·27	46	...	
Barley flour, .	13·0	2·20	1·90	55	...	

*Th. Thaer—Bl. Block—M. Midleton—En. Einhoff—Sch. Schwartz—Mr. Murre.

The following Table, from the same source, contains substances, several of which are almost exclusively used as the food of man. Flour of wheat is taken as the standard and estimated at 100. As tubers, roots, and leaves, may be ground when dried at 212°, these dried matters are in the Table designated flour. The equivalents are all *theoretical*, that is, they are calculated from the nitrogen contained, and they express the weights of the respective substances that are equivalent to 100 parts of wheat flour :—

SUBSTANCES.	EQUIVALENTS.	SUBSTANCES.	EQUIVALENTS.
Wheat Flour	100	Haricots, white	56
Wheat	107	Lentils	57
Flour of Barley	119	Hearted Cabbage, white	810
Barley	130	Flour of do.	61
Rye	111	Potatoes	613
Buck Wheat	108	Flour of do.	126
Maize	138	Carrots	757
Beans	44	Flour of do.	95
Peas, yellow	67	Turnips	1335

The following Table of the comparative value of different kinds of fodder is translated by the Rev. Mr. RHAM from the French of M. ANTOINE. It is extracted from the *Journal of the Royal Agricultural Society of England*, Vol. III. Part I.

	lbs.		lbs.
Good hay	100	Dried stalks of Jerusalem artichokes	170
are equal in nourishment to		Dried stalks of Indian corn	400
Lattermath hay	102	Millet straw	250
Clover, hay-made, (when the blossom is completely developed)	90	Raw potatoes	201
		Boiled ditto	175
Ditto, (before the blossom expands)	88	White Silesian beet	220
		Mangold-wurzel	339
Clover, second crop	98	Turnips	504
Lucerne hay	98	Carrots	276
Sainfoin hay	89	Collkalis	287
Tare hay	91	Swedish turnips	308
Spurrey, dried	90	Ditto with the leaves on	350
Clover hay, after the seed	146	Grain—Rye	54
Green clover	410	Wheat	45
Vetches or tares, green	457	Barley	54
Green Indian corn	275	Oats	59
Spurrey, green	425	Vetches	50
Stems and leaves of Jerusalem artichokes	325	Peas	45
		Beans	45
Cow cabbage leaves	541	Buckwheat	64
Beet-root leaves	600	Indian corn	57
Potatoe halm	300	French beans, dried	32
Shelter wheat straw	374	Chestnuts	47
Rye straw	442	Acorns	68
Oat straw	195	Horse-Chestnuts	50
Peas halm	153	Sun-flower seed	62
Vetch halm	159	Linseed cake	69
Bean halm	140	Wheat bran	105
Buckwheat straw	195	Rye bran	109

Wheat, peas, and oat chaff	167	Dried Oak leaves . .	83
Rye and barley chaff .	179	Do. Canada poplar leaves	67
Dried lime-tree leaves .	73		

On comparing ANTOINE's Table with that of BOUSSINGAULT, considerable differences will be found, and it is not singular it should be so, for the proportion of water to the dry organic matter of crops varies with the soil, climate, season, varieties cultivated, length of time and condition in which the aliment has been kept, as well as in other respects. Thus grain thrashed out in November contains more water than what has lain for months in the stack or granary. New hay contains less nourishment, weight for weight, than old hay—the wheat of southern Europe contains more fibrine and gluten and less starch than that of northern Europe—fine bright seasons assimilate the produce of higher and colder latitudes to that of better climates—and one variety of crop is naturally richer in nutritive matter than another; as the Swedish Turnip, which contains more sugar and azotized matter than the globe turnip. To these causes of variation may be also added, that some practical men have not distinguished between a sustaining and a fattening ration; and hence the practical equivalents of the most intelligent and careful experimentalists are alone worthy of credit, and their numbers are, in this respect, much more to be depended upon than *means* deduced from numerous authorities, some of them doubtful.

In constructing Tables of Practical Equivalents, it is especially worthy of notice, that theoretical results should not be combined with them in deducing means. When the numerous fallacies inseparable from the determination of practical equivalents are considered, the necessity of a more copious induction becomes apparent, but this should not tempt us to supply the deficiency with theoretical results. Theoretical equivalents are, as yet, based on but a few unexceptionable analyses, and hence, in the present state of our knowledge, to mix the two is to benefit neither.

Did we possess a sufficient number of trustworthy analyses of the inorganic constituents of the plants in ordinary culture, it would be in the highest degree desirable to compare with the equivalents already deduced another series based on the phosphorus and sulphur contained in them—these bodies having been shown to enter into the composition of albumen, fibrine, and caseine—the principles in vegetables that chiefly contribute to the construction and repair of organized tissues in animals. And lastly, our knowledge would be greatly advanced by having yet another series of equivalents, based on the neutral proximate principles of aliments—the starch, gum, sugar, &c.—substances which LIEBIG has shewn to minister to the respiratory function, and to the formation of unorganized matter in the animal, namely, fat.

In connexion with these Tables, and as a basis for calculations that will occur afterwards, the following Tables of ultimate analyses are added. They are translated from a paper by BOUSSINGAULT, *Annales de Chimie*, Feb., 1841, on the Rotation of Crops—one of the most valuable contributions to Agricultural Science.

PROPORTION OF WATER AND DRY ORGANIC MATTER IN SOME OF THE PLANTS OF ORDINARY CULTURE.

The Substances were first Dried in the Stove, and the Desiccation afterwards completed in Vacuo at 230° *F.*

Substances.	Dry Matter, per Cent.	Water, per Cent.
Wheat	85·5	14·5
Rye	83·4	16·6
Oats	79·2	20·8
Straw of wheat	74·0	26·0
Do. of rye	81·3	18·7
Do. of oats	71·3	28·7
Potatoes	24·1	75·9
Mangold-wurzel	12·2	87·8
Turnips	7·5	92·5
Jerusalem Artichokes	20 8	79·2
Peas	91·4	8·6
Straw of Peas	88·2	11·8
Clover hay	79·0	21·0
Stems of Jerusalem Artichokes	87·1	12·9

ULTIMATE ANALYSES OF CROPS.

(Dried in Vacuo, at the Temperature of 230° *F.)*

Substances.	Ashes included.					Ashes deducted.			
	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ashes.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.
Wheat	46·1	5·8	43·4	2·3	2·4	47·2	6·0	44·4	2·4
Rye	46·2	5·6	44·2	1·7	2·3	47 3	5·7	45·3	1·7
Oats	50·7	6·4	36·7	2·2	4·0	52·9	6·6	38 2	2·3
Straw of wheat	48·4	5·3	38·9	0·4	7·0	52·1	5·7	41·8	0·4
Do. of rye	49·9	5·6	40·6	0·3	3·6	51·8	5·8	42·1	0·3
Do. of oats	50·1	5·4	39·0	0·4	5·1	52·8	5·7	41·1	0·4
Potatoes	44·0	5·8	44·7	1·5	4·0	43·9	6·1	46·4	1·6
Mangold-wurzel	52·8	5·8	43·4	1·7	6·3	45·7	6·2	46·3	1·8
Turnips	42·9	5·5	42·3	1·7	7·6	46·3	6·0	45·9	1·8
Jerusalem Artichokes	43·3	5·8	43·3	1·6	6·0	46·0	6·2	46·1	1·7
Peas, yellow	46·5	6·2	40·0	4·2	3·1	48·0	6·4	41·3	4·3
Straw of peas	45·8	5·0	35·6	2·3	11·3	51·5	5·6	40·3	2·6
Hay of red clover	47·4	5·0	37·8	2·1	7·7	51·3	5·4	41·1	2·2
Stems of Jerusalem Artichokes	45·7	5·4	45·7	0·4	2·8	47·0	5·6	47·0	0·4

LECTURE IV

ON SOILS—THEIR CONSTITUENT PARTS—ON THE ANALYSIS OF SOILS—OF THE USES OF THE SOIL—OF THE ROCKS AND STRATA FOUND BENEATH SOILS—OF THE IMPROVEMENT OF SOIL.

No SUBJECTS are of more importance to the farmer than the nature and improvement of soils; and no parts of the doctrines of agriculture are more capable of being illustrated by chemical enquiries.

Soils are extremely diversified in appearance and quality; yet, as it was stated in the Introductory Lecture, they consist of different proportions of the same elements; which are in various states of chemical combination, or mechanical mixture.

The substances which constitute soils have been already mentioned. They are certain compounds of the earths, silica, lime, alumina, magnesia, and of the oxides of iron and manganesum; animal and vegetable matters in a decomposing state, and saline, acid or alkaline combinations.

In all chemical experiments on the composition of soils connected with agriculture, the constituent parts obtained are compounds; and they act as compounds in nature; it is in this state, therefore, that I shall describe their characteristic properties.

1. SILICA, or the earth of *flints*, in its pure and crystallized form, is the substance known by the name of rock crystal, or Cornish diamond. As it is procured by chemists, it appears in the form of a white impalpable powder. It is not soluble in the common acids, but dissolves by heat in fixed alkaline lixivia. It is an incombustible substance, for it is saturated with oxygen. I have proved it to be a compound of oxygen, and the peculiar combustible body which I have named silicum; and from the experiments of Berzelius, it is probable that it contains nearly equal weights of these two elements. *

2. The sensible properties of *lime* are well known. It exists in soils usually united to carbonic acid; which is easily disengaged from it by the attraction of the common acids. It is sometimes found combined with the phosphoric and sulphuric acids. Its chemical properties and agencies in its pure state will be described in the Lecture on manures obtained from the mineral kingdom. It is soluble in nitric and muriatic acids, and forms a substance with sulphuric acid, difficult of solution, called gypsum. It

* Silica, or Silicic acid, consists of 48·4 of silicon and 51·6 of oxygen. Chemists are not agreed as to its atomic constitution. Thomson considers it as composed of single equivalents, others regard it as composed of one of silicon to two of oxygen, while Berzelius holds it as consisting of one of silicon to three of oxygen.

Silicic acid occurs pure in rock crystal, and with small quantities of water, alumina and iron, in quartz, flint, calcedony, agate, &c. Silicic acid combined with alumina, lime, magnesia, oxide of iron, and alkalies, is found in an immense

is not soluble in alkaline solutions. It consists of one proportion 40 of the peculiar metallic substance, which I have named calcium; and one proportion 15 of oxygen. *

3. ALUMINA exists in a pure and crystallized state in the white sapphire, and united to a little oxide of iron and silica in the other oriental gems. In the state in which it is procured by chemists, it appears as a white powder, soluble in acids and fixed alkaline liquors. From my experiments, it appears that alumina consists of one proportion 33 of aluminum, and one 15 of oxygen. †

4. MAGNESIA exists in a pure crystallised state, constituting a mineral like talc found in North America. In its common form it is the *magnesia usta*, or calcined magnesia of druggists. It generally exists in soils combined with carbonic acid. It is soluble in all the mineral acids; but not in alkaline lixivia. It is distinguished from the other earths found in soils

number of minerals, especially those of common occurrence. The following table shews the percentage of silicic acid in those minerals and rocks from whose decomposition soils generally result.

	SILICIC ACID, in 100 parts.	
Rock crystal, quite pure	100·00	
Hornstone	98·25	Klaproth.
Flint	98·00	do.
Jasper	75·00	Kirwan.
Albite	70·67	Stromeyer.
Felspar	64·20	Berthier.
Talc slate	57·56	Thomson.
Clinkstone	57·25	Klaproth.
Clay slate	49·23	Thomson.
Mica	46·35	Rose.
Hornblende	42·24	Bonsdorf.
Serpentine	28·25	Thomson.

* The composition of lime is represented by the formula CaO, its equivalent is 28·5. Lime abounds in all the limestones, chalks, and marls, and in soils formed from these substances; limestones and marls vary in purity as will be noticed in the lecture on mineral manures. Lime occurs in *gypsum* which is composed of lime, sulphuric acid and water. It occurs also in most minerals from the decomposition of which soils result. In silicious minerals its quantity is by no means inconsiderable. The following table shews the per centage of lime in some of the most generally diffused minerals:—

	LIME, in 100 parts.	
Pure limestone	56·30	
Gypsum	32·91	
Dolomite	29·20	Berthier.
Augite	22·1	Rose.
Hornblende	12·24	Bonsdorf.
Talc slate	7·94	Thomson.
Mica	0· to 6·1	Do.
Clay slate	5·54	Do.

† Davy and Thomson considered alumina as a protoxide. From the analogy subsisting between alumina and peroxide of iron, almost all other chemists regard it as a sesquioxide,—that is, composed of 2 equivalents of aluminium and 3 equivalents of oxygen $Al_2 O_3$. Its equivalent is 51·4.

Alumina with a trace of colouring matter constitutes the ruby and sapphire, and with small quantities of silica and oxide of iron it occurs in diamond-spar and emery. Alumina occurs in almost all soils from the decomposition of the

by its ready solubility in solutions of alkaline carbonates, saturated with carbonic acid. It appears to consist of 38 magnesium and 15 oxygen. *

5. There are two well known *oxides of iron*, the black and the brown. The black is the substance that flies off when red hot iron is hammered.

The brown oxide may be formed by keeping the black oxide red hot, for a long time in contact with air. The first seems to consist of one proportion of iron 103, and two of oxygen 30; and the second of one proportion of iron 103, and three proportions of oxygen 45. The oxides of iron sometimes exist in soils combined with carbonic acid. They are easily distinguished from other substances by their giving when dissolved in acids a black colour to solution of galls, and a bright blue precipitate to solution of prussiate of potassa and iron. †

6. THE OXIDE OF MANGANESUM is the substance commonly called manganese, and used in bleaching. It appears to be composed of one pro-

more common aluminous minerals. In clay it exists partly as a hydrate, but principally in combination with silica, oxide of iron, manganese, lime, magnesia and alkalies. The greater the proportion of hydrate of alumina, the more stiff and tenaceous is the clay.

The following table shews the proportion of alumina in the most abundant aluminous minerals:—

	ALUMINA, in 100 parts.	
Schorl - - - - - - -	38·23	Gmelin.
Mica - - - - - - -	36·8	Rose.
Porcelain clay - - - - - -	34·6	Berthier.
Chlorite - - - - - - -	23·70	Thomson.
Clinkstone - - - - - - -	23·50	Klaproth.
Albite - - - - - - -	19·8	Stromeyer.
Common Garnet - - - - - -	19·66	Hisinger.
Felspar - - - - - - -	18·40	Berthier.
Clay slate - - - - - - -	14·56	Thomson.
Hornblende - - - - - -	13·92	Bonsdorf.
Serpentine - - - - - -	6·45	Thomson.

* Magnesia is represented by the formula MgO, its equivalent is 20·7.

Magnesia occurs in most soils in greater or less quantity, and is an essential constituent of many of the plants usually cultivated. In cretaceous soils, and those formed from the decomposition of magnesian limestone, magnesia exists in combination with carbonic acid. In many soils magnesia exists in combination with silicic acid. In some cases magnesia is found in soils combined with phosphoric acid.

The per centage of magnesia, in some of the more common magnesian minerals, is shewn in the following table:—

	MAGNESIA, in 100 parts.	
Serpentine - - - - - - -	33·1	Thomson.
Talc - - - - - - -	30·53	do.
Talc slate - - - - - - -	27·21	do.
Dolomite - - - - - - -	21·2	Berthier.
Achynolite - - - - - - -	21·1	Bonsdorf.
Chlorite - - - - - - -	14·3	Berthier.
Hornblende - - - - - - -	13·74	Bonsdorf.
Augite - - - - - - -	4·99	Rose.
Do. - - - - - - -	15·25	do.
Clay slate - - - - - - -	2·24	Thomson.

† There are two oxides of iron that form the bases of pure salts, the protoxide and the peroxide. These two oxides are capable of uniting to form what is termed the black or magnetic oxide. The peroxide and black oxide occur ex-

portion of manganesum 113, and three of oxygen 45. It is distinguished from the other substances found in soils, by its property of decomposing muriatic acid, and converting it into chlorine. *†

tensively as ores of iron. The carbonate of protoxide is also an important ore, sometimes occurring pure, but more frequently along with clay and siliceous matters. The three oxides are represented by the following formulæ:—

Protoxide FeO.
Peroxide $Fe_2 O_3$
Black oxide $FeO + Fe_2O_3$

From the circumstance that iron occurs in a great many minerals, either as an essential constituent or adventitiously, it follows that it will be found in almost all soils. When it occurs in combination with sulphur, or in a low state of oxidation, as it does in many subsoils, clays, clay marls, &c, it is very prejudicial to vegetation. On exposure, however, it passes into the state of peroxide and assumes a red or brown colour, and in this state, as appears from the large proportion in which it is found in many highly fertile soils, it is not merely not prejudicial but forms a very useful constituent.

The following table exhibits the percentage of the oxides of iron found in the most common ores, as well as in those minerals of common occurrence, by whose disintegration soils are produced:—

	Protoxide. in 100 parts.	Peroxide. in 100 parts.	
Red Hæmatite, pure	...	100·	
Magnetic iron ore	31·	69·	
Brown Hæmatite	...	81·63	
Iron Pyrites - iron 46·51	...	...	
Clay ironstone	47·33	...	Colquhoun.
Bog iron ore	...	61·0	Daubuisson.
Common garnet	33·57	...	Wachtmeister.
Chlorite	23 5	...	Berthier.
Clay slate	20·77	...	Thomson.
Do.	11·45	...	do.
Augite	17·38	...	Rose.
Hornblende	16 26	...	Bonsdorf.
Basalt	16·00	...	Kennedy.
Jaspar	...	13·0	Kirwan.
Mica	...	7·31	Thomson.
Talc slate	4·71	...	do.
Clinkstone	...	3 25	Klaproth.
Felspar—from a trace to	3·00	...	Various.

*There are many compounds of manganese and oxygen The most common is the grey oxide, which, when pure, is an hydrous binoxide. The protoxide occurs in numerous minerals, variously combined Oxides of manganese are consequently found in many soils, but have not been shewn to be ingredients of importance.

The following table exhibits the percentage of manganese in some of the more common minerals in which it occurs:—

	Protoxide. in 100 parts	Peroxide. in 100 parts.	
Grey oxide	...	97·83	Turner.
Common Garnet	5·49	...	Wachtmeister.
Hypersthene	5·29	...	Muir.
Hornblende, from a trace to	2·00	...	Various.

Although not to be regarded as an essential constituent oxide of manganese occurs in small and variable proportion in many magnesian and aluminous minerals.

† Fixed alkalies (potash and soda) occur in some of the most generally distributed minerals from which soils are derived; they also occur in the ashes of all

7. VEGETABLE AND ANIMAL MATTERS are known by their sensible qualities, and by their property of being decomposed by heat. Their characters may be learned from the details in the last Lecture.

8. The SALINE COMPOUNDS found in soils, are common salt, sulphate of magnesia, sometimes sulphate of iron, nitrates of lime and of magnesia sulphate of potassa, and carbonates of potassa and soda. To describe their characters minutely will be unnecessary; the tests, for most of them have been noticed page 64, [See also Appendix to Lecture IV.—S.]

The silica in soils is usually combined with alumina and oxide of iron, or with alumina, lime, magnesia, and oxide of iron, forming gravel and sand of different degrees of fineness. The carbonate of lime is usually in an impalpable form; but sometimes in the state of calcareous sand. The magnesia, if not combined in the gravel and sand of soil, is in a fine powder united to carbonic acid. The impalpable part of the soil, which is usually called clay or loam, consists of silica, alumina, lime, and magnesia; and is, in fact, usually of the same composition as the hard sand, but more finely divided. The vegetable or animal matters (and the first is by far the most common in soils) exist in different states of decomposition. They are sometimes fibrous, sometimes entirely broken down and mixed with the soil.

To form a just idea of soils, it is necessary to conceive different rocks decomposed, or ground into parts and powder of different degrees of fineness; some of their soluble parts dissolved by water, and that water adhering to the mass, and the whole mixed with larger or smaller quantities of the remains of vegetables and animals, in different stages of decay.

plants. In soils, in their natural state, the decomposing minerals afford alkalies in quantities sufficient for the plants growing in these soils; or what is equivalent to the same thing, only such plants as can find the requisite supply continue to grow in these soils. In our cultivated fields the case is different. We must produce particular plants, those most valuable as food for man and the domesticated animals, and in quantity sufficient to yield a profit. Only some of our soils can afford enough of alkaline matter for the profitable production of these crops, and hence, to those that are deficient, manures rich in alkalies must be frequently applied. But it is obvious that since all soils do not require alkaline manures, or the same amount of them, it is desirable to know their capabilities in this respect, and in the analysis of soils and manures, the determination of alkalies ought to be scrupulously attended to. These remarks apply with as much force to Phosphoric acid, another essential constituent of fertile soils, always found in the plants of agriculture, and too frequently overlooked in analysis of soils.

The following table shews the percentage of alkalies in some common minerals from which soils are derived:—

	POTASH. in 100 parts.	
Felspar	16·95	Berthier.
Mica	9·22	Rose.
Porcelain clay	8·2	Berthier.
Clay slate	4·7	Daubuisson.
Chlorite	2·7	Berthier.
	SODA. in 100 parts.	
Albite	9·0	Stromeyer.
Labradorite	4·39	Thomson.

It is probable that alkalies have often been overlooked in analyses, and that were more attention given to the composition of rocks and aggregated minerals, small quantities of these substances would be found in many cases where their presence is not suspected.

It will be necessary to describe the processes by which all the varieties of soils may be analysed. I shall be minute in these particulars, and, I fear, tedious,; but the philosophical farmer will, I trust, feel the propriety of full details on this subject.

The instruments required for the analysis of soils are few, and but little expensive.* They are a balance capable of containing a quarter of a pound of common soil, and capable of turning when loaded, with a grain; a set of weights from a quarter of a pound Troy to a grain;† a wire sieve, sufficiently coarse to admit a mustard seed through its apertures;‡ an

* If an accurate analysis is to be attempted—and such only can be of any real service—the operator will require several pieces of apparatus not mentioned in the text. These are partly noticed in the notes that immediately follow, but principally in the appendix to this lecture, when treating of the processes in which they are employed. The best English works on Chemical Apparatus, and the modes of using it, to which the student can be referred, are FARADAY'S "*Chemical Manipulation*," and GRIFFIN'S "*Chemical Manipulation and Analysis by the Blowpipe*."

† A delicate balance is absolutely necessary for conducting chemical analysis, but as it has been found more accurate and expeditious to operate on smaller quantities than were formerly employed, it is necessary to weigh with greater accuracy. A balance capable of being loaded with 500 or 600 grains in each scale, and of turning when so loaded, with the hundredth of a grain, is the kind of one found most useful in analysis. Such a balance is rather expensive, but it is not possible to proceed a step without it. A fine balance should always be protected by a glass-case, and never exposed to fumes in the laboratory. Occasionally it may be necessary to use it in the laboratory, but it should be removed as soon as the operation of weighing is finished. For common purposes, where great accuracy is not required, and to save the fine balance, the balance sold under the name of "Apothecaries' Scales," may be employed. Accurately adjusted brass weights, from 500 grains to 1 grain, are employed, the 10ths and 100ths of a grain are best made of platinum wire: the smaller weights are lifted by a forceps.

Before using the balance, it must be ascertained that the scales exactly balance each other, and if not, the equilibrium is restored by means of a clipping of tinfoil. Currents of air are to be avoided, and when a crucible and its contents are to be weighed after ignition, the temperature must be allowed to fall to such a degree, that the accuracy of the result shall not be affected by a hot air current upwards from the scale containing the crucible. At the same time it should be remembered, that many substances, after ignition, rapidly increase in weight by attracting moisture from the atmosphere, hence, the cover of the crucible should be kept on, and the weighing performed as soon as it is cold enough to be handled. A little practice, however, will lead the student to detect errors that arise from this source.

In using the balance, the operator should always put the substances to be weighed into the *same* scale. By observing this rule, although the balance is not quite accurate, the results are all proportional. By using the method of double weighing, perfectly accurate results are obtained with a false balance, provided it is delicate. This method will be best understood by an example. Suppose 500 grains of a substance are to be accurately weighed, the 500 grain weight is put into one scale, and accurately counterpoised by small shot or any convenient substance in the other, the weight is then removed from the first scale, and the substance introduced in its place till the equilibrium is restored. Here it is manifest that whether the balance is true or false, since the 500 grains and the substance to be weighed have successively counterpoised the same thing, they must be equal to one another.

‡ It is better to employ several sieves.—See Appendix.

Argand lamp and stand; * some glass bottles; Hessian crucibles; † porcelain, or queen's ware, evaporating basins; a Wedgewood pestle and mor-

* Where coal gas is not at command, an Argand lamp may be useful for evaporations, but it cannot, on account of the smoke of an oil flame, be used in igniting crucibles, capsules, &c. For this purpose a small furnace may be used and a sand bath attached, will be found very serviceable. Platinum crucibles, when ignited in the furnace, are protected from the fuel by crucible-cases of fire-clay, (Fig. 15,) which answer better in every way than the Hessian crucibles generally employed as cases.

The German spirit lamp, with circular wick, (Fig. 16) is also much used for igniting platinum crucibles and capsules, but I find the wire-gauze gas-burner described in the appendix, both more manageable and economical.

Fig. 16.

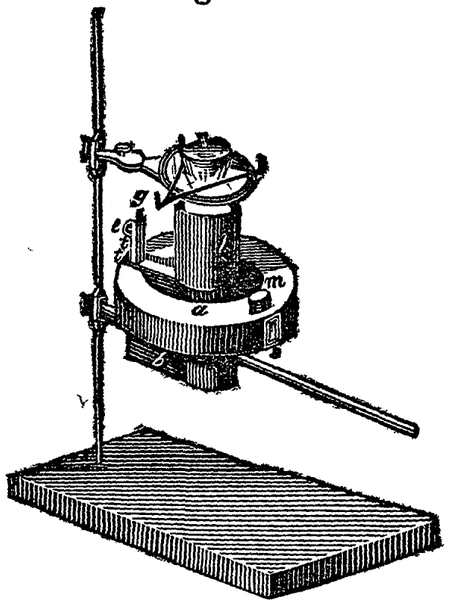
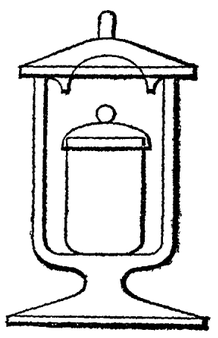


Fig. 15.



† When accuracy is necessary, Hessian crucibles are inadmissible. It is impossible to analyse a soil without the use of certain platinum vessels, such as a small crucible, without a cover, for burning Filters, weighing, &c. (Fig. 17); a larger crucible, of the same shape, for igniting larger quantities; one, or better, two capsules, (Figs. 18 and 20); a platinum spatula is also very useful, and a steel forceps with platinum points, (Fig 21).

Fig. 17.

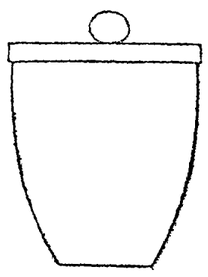


Fig. 18.

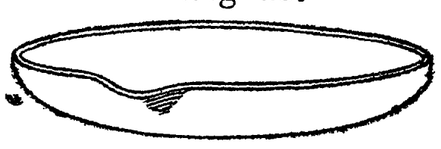
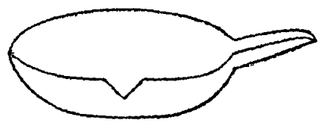


Fig. 20.



For some purposes Berlin porcelain crucibles, (Figs. 22 and 23,) may be substituted.—See Appendix.

Fig. 21.

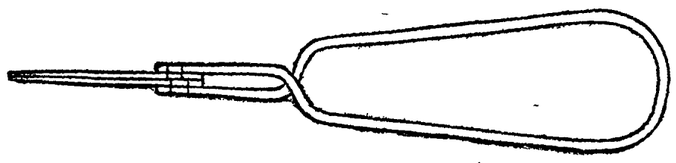
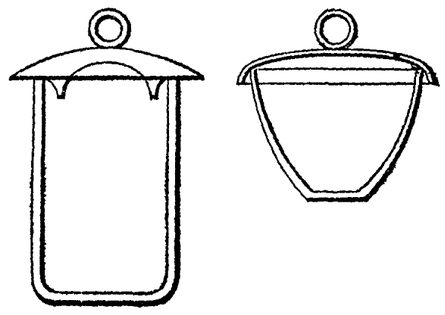


Fig. 22 and 23.



tar; some filtres made of half a sheet of blotting paper, folded so as to contain a pint of liquid, and greased at the edges;* a bone knife, and an apparatus for collecting and measuring aeriform fluids.

The chemical substances, or reagents, required for separating the constituent parts of the soil, have, for the most part, been mentioned before: they are muriatic acid *(spirit of salt)*, sulphuric acid, pure volatile alkali dissolved in water, solution of prussiate of potash and iron, succinate of ammonia, soap lye, or solution of potassa, solutions of carbonate of ammonia, of muriate of ammonia, of neutral carbonate of potash, and nitrate of ammonia.

In cases when the general nature of the soil of a field is to be ascertained, specimens of it should be taken from different places, two or three inches below the surface, and examined as to the similarity of their properties. It sometimes happens, that upon plains the whole of the upper stratum of the land is of the same kind, and in this case, one analysis will be sufficient; but in vallies and near the beds of rivers, there are very great differences, and it now and then occurs that one part of a field is calcareous, and another part siliceous; and in this case, and in analogous cases, the portions different from each other should be separately submitted to experiment.†

Soils when collected, if they cannot be immediately examined, should be preserved in phials quite filled with them, and closed with ground glass stoppers.

The quantity of soil most convenient for a perfect analysis, is from two to four hundred grains.‡ It should be collected in dry weather, and exposed to the atmosphere till it becomes dry to the touch.

* It is necessary to guard the student against using ordinary blotting paper. Its colouring matter and the coarseness and impurity of the materials from which it is made, render it inadmissible. White blotting paper, if free from lime and acids, and sufficiently thin to permit the operation to go on quickly, is what should be used. Such an article, however, is not always to be met with. For a considerable time I have used Griffin's cut filter papers, and find them much superior to all other kinds. As the paper is very uniform in thickness, the weight of the filter requires simply to be multiplied by .0042 to obtain the weight of paper-ashes to be deducted, in cases where a precipitate has been ignited along with the filter paper. If a suitable funnel is employed, and evaporation prevented by a plate of glass laid across its mouth, greasing the edges—a practice objectionable on many accounts, is quite unnecessary.

† A very common occurrence of this kind is to find in a field, otherwise fertile, a few patches almost barren, where plants, especially when the field is in white crop, spring up, and for a time look quite healthy, but soon become diseased, assume a yellow colour, and die. Specimens from such parts should, on no account, be mixed with the rest. They should be examined by themselves, and the results compared with those given by the fertile parts. By following this course, the cause of sterility, and the means of curing it, are most likely to be discovered.

‡ For the determination of some constituents, this quantity is insufficient. The soluble saline matter could not be determined with sufficient accuracy from one or two hundred grains, and the phosphoric acid, even although present in quantity more than sufficient for the crops usually cultivated, might easily, when operating on a small quantity, be entirely overlooked. It is therefore expedient, in collecting specimens of soils for analysis, to have from one to two pounds of each. Many of the constituents can be best determined from small quantities, say 40 or 50 grains, but when the substances sought are important, and present only in small quantity, it is necessary to operate on much greater weights.

The specific gravity of a soil, or the relation of its weight to that of water, may be ascertained by introducing into a phial, which will contain a known quantity of water, equal volumes of water and of soil, and this may be easily done by pouring in water till it is half full, and then adding the soil till the fluid rises to the mouth; the difference between the weight of the soil and that of the water, will give the result. Thus if the bottle contains four hundred grains of water, and gains two hundred grains when half filled with water and half with soil, the specific gravity of the soil will be 2, that is it will be twice as heavy as water, and if it gained one hundred and sixty-five grains, its specific gravity would be 1825, water being 1000.*

* Specific gravity bottles containing exactly 500 grains of distilled water at 60° F. when the stopper is introduced, may be had of dealers in Chemical Apparatus, adjusted and sold along with a counterpoising weight. A 500 grain bottle is preferred to one containing 1000 grains, on account of its not overloading a balance of the size already mentioned, and an adjusted stopper is obviously more accurate than a mark on the neck. The bottle with its stopper is placed in one of the scales of the balance and counterpoised, 375 grains of distilled water are carefully weighed into it, and the soil whose specific gravity is to be determined, is introduced till the water has risen as high as admits of the introduction of the stopper, without overflowing, or leaving any air between the surface of the water and the stopper. The increase of weight is then ascertained. The reason why the bottle must be filled three fourths with water and one fourth with soil in place of equally with water and soil as recommended in the text is, that in the latter case there is not water enough to moisten the soil so as to permit the rise of the water to be accurately observed, and the air bubbles to escape. Indeed, when an attempt is made with equal bulks of water and soil, the water is so completely absorbed that even before the whole vacant space is filled up, the bottle may be inverted without the escape of a single drop of water. Hence it is impossible to take the specific gravity in this manner. When, however, the bottle is filled three-fourths with water, even with the stiffest clays, the process is easy, provided the soil (which should be previously exposed to the air till it is dry) is added in small quantities at a time, and the air bubbles permitted to rise and break before weighing.

The calculation is obvious. For when equal bulks of different bodies are taken, their specific gravities are as their weights. Indeed the process just described is merely a contrivance for weighing equal bulks. It has been shown that in practice equal bulks cannot be used; this however does not interfere with the calculation, for since the bottle has been filled three-fourths with water, it is clear that one third of this weight or 125 grains ($3\frac{7}{3}5$) is the weight of water equal in bulk to the soil employed. Water is taken as the standard of comparison for all solid and liquid bodies, and its specific gravity is generally estimated at unity. Hence the weight of the soil, say 300 grains, requires merely to be divided by the weight of an equal bulk of water 125 grains, and the quotient 2·4 is the specific gravity of the soil in the case supposed.

The last three soils whose density I had occasion to determine gave the following results, which are mentioned as instances of what the student may expect to meet with.

No. 1, A sandy clay soil derived from the decomposition of Grauwacke rocks, containing but a small percentage of organic matter, and yielding but inferior crops, chiefly from the want of drainage. Specific gravity 2·335.

No 2, A stiff clayey soil reclaimed from a very tenacious diluvial clay, a fair wheat soil Specific gravity 2.276.

No. 3, A very fertile sandy loam, long in culture, and derived originally from the decomposition of gneiss. Specific gravity 2·150.

There is reason to believe that were there published a sufficient number of observations on the specific gravity of soils compared with their chemical con-

It is of importance, that the specific gravity of a soil should be known, as it affords an indication of the quantity of animal and vegetable matter it contains; these substances being always most abundant in the lighter soils.

The other physical properties of soils should likewise be examined before the analysis is made, as they denote, to a certain extent, their composition, and serve as guides in directing the experiments. Thus siliceous soils are generally rough to the touch, and scratch glass when rubbed upon it; ferruginous soils are of a red or yellow colour; and calcareous soils are soft.*

1. Soils, though as dry as they can be made by continued exposure to air, in all cases still contain a considerable quantity of water, which adheres with great obstinacy to the earths and animal and vegetable matter, and can only be driven off from them by a considerable degree of heat. The first process of analysis is, to free the given weight of soil from as much of this water as possible, without in other respects, affecting its composition; and this may be done by heating it for ten or twelve minutes over an Argand lamp, in a basin of porcelain, to a temperature equal to 300° Fahrenheit; and if a thermometer is not used, the proper degree may be easily ascertained, by keeping a piece of wood in contact with the bottom of the dish; as long as the colour of the wood remains unaltered, the heat is not too high; but when the wood begins to be charred, the process must be stopped. A small quantity of water will perhaps remain in the soil even after this operation, but it always affords useful comparative results; and if a higher temperature were employed, the vegetable or animal matter would undergo decomposition, and in consequence the experiment be wholly unsatisfactory.

The loss of weight in the process should be carefully noted, and when in four hundred grains of soil it reaches as high as 50, the soil may be considered as in the greatest degree absorbent, and retentive of water, and will generally be found to contain much vegetable or animal matter, or a large proportion of aluminous earth. When the loss is only from 20 to 10, the land may be considered as only slightly absorbent and retentive, and siliceous earth probably forms the greatest part of it.

2. None of the loose stones, gravel, or large vegetable fibres should be divided from the pure soil till after the water is drawn off; for these bodies are themselves often highly absorbent and retentive, and in consequence influence the fertility of the land. The next process, however, after that of heating, should be their separation, which may be easily accomplished by the sieve, after the soil has been gently bruised in a mortar. The weights of the vegetable fibres or wood, and of the gravel and stones, should be separately noted down, and the nature of the last ascertained; if calcareous, they will effervesce with acids; if siliceous, they will be sufficiently hard to scratch glass; and if of the common aluminous class of stones, they will be soft, easily cut with a knife, and incapable of effervescing with acids.

stitution and productiveness, a connexion between the two would be made out, and that the determination of the density, might in some cases go far to render more elaborate examinations unnecessary. Although it would be wrong to hazard any generalizations in the present state of our knowledge, the subject merits the attention of practical men and observers.

* So many deviations from the process of analysis described in the text have been made, that for the sake of clearness, the whole details have been transferred to the appendix to this lecture.

3. The greater number of soils, besides gravel and stones, contain larger or smaller proportions of sand of different degrees of fineness; and it is a necessary operation, the next in the process of analysis, to detach them from the parts in a state of more minute division, such as clay, loam, marle, vegetable and animal matter, and the matter soluble in water. This may be effected in a way sufficiently accurate, by boiling the soil in three or four times its weight of water; and when the texture of the soil is broken down, and the water cool; by agitating the parts together, and then suffering them to rest. In this case, the coarse sand will generally separate in a minute, and the finer in two or three minutes, whilst the highly divided earthy, animal, or vegetable matter will remain in a state of mechanical suspension for a much longer time; so that by pouring the water from the bottom of the vessel, after one, two or three minutes, the sand will be principally separated from the other substances, which, with the water containing them, must be poured into a filter, and after the water has passed through, collected, dried, and weighed. The sand must likewise be weighed, and the respective quantities noted down. The water of lixiviation must be preserved, as it will be found to contain the saline and soluble animal or vegetable matters, if any exist in the soil.

4. By the process of washing and filtration, the soil is separated into two portions, the most important of which is generally the finely divided matter. A minute analysis of the sand is seldom or never necessary, and its nature may be detected in the same manner as that of the stones or gravel. It is always either siliceous sand, or calcareous sand, or a mixture of both. If it consist wholly of carbonate of lime, it will be rapidly soluble in muriatic acid, with effervescence; but if it consist partly of this substance, and partly of siliceous matter, the respective quantities may be ascertained by weighing the residuum after the action of the acid, which must be applied till the mixture has acquired a sour taste, and has ceased to effervesce. This residuum is the siliceous part; it must be washed, dried, and heated strongly in a crucible; the difference between the weight of it and the weight of the whole, indicates the proportion of calcareous sand.

5. This finely divided matter of the soil is usually very compound in its nature; it sometimes contains all the four primitive earths of soils, as well as animal and vegetable matter; and to ascertain the proportions of these with tolerable accuracy, is the most difficult part of the subject.

The first process to be performed, in this part of the analysis, is the exposure of the fine matter of the soil to the action of muriatic acid. This substance should be poured upon the earthy matter in an evaporating bason, in a quantity equal to twice the weight of the earthy matter; but diluted with double its volume of water. The mixture should be often stirred, and suffered to remain for an hour, or an hour and a half, before it is examined.

If any carbonate of lime or of magnesia exist in the soil, they will have been dissolved in this time by the acid, which sometimes takes up likewise a little oxide of iron; but very seldom any alumina.

The fluid should be passed through a filter; the solid matter collected, washed with rain water, dried at a moderate heat, and weighed. Its loss will denote the quantity of solid matter taken up. The washings must be added to the solution, which if not sour to the taste, must be made so by the addition of fresh acid, when a little solution of prussiate of potassa and iron must be mixed with the whole. If a blue precipitate occurs, it denotes the presence of oxide of iron, and the solution of the prussiate

must be dropped in till no further effect is produced. To ascertain its quantity, it must be collected in the same manner as other solid precipitates, and heated red; the result is oxide of iron, which may be mixed with a little oxide of manganesum.

Into the fluid freed from oxide of iron, a solution of neutralized carbonate of potash must be poured till all effervescence ceases in it, and till its taste and smell indicate a considerable excess of alkaline salt.

The precipitate that falls down is carbonate of lime; it must be collected on the filter, and dried at a heat below that of redness.

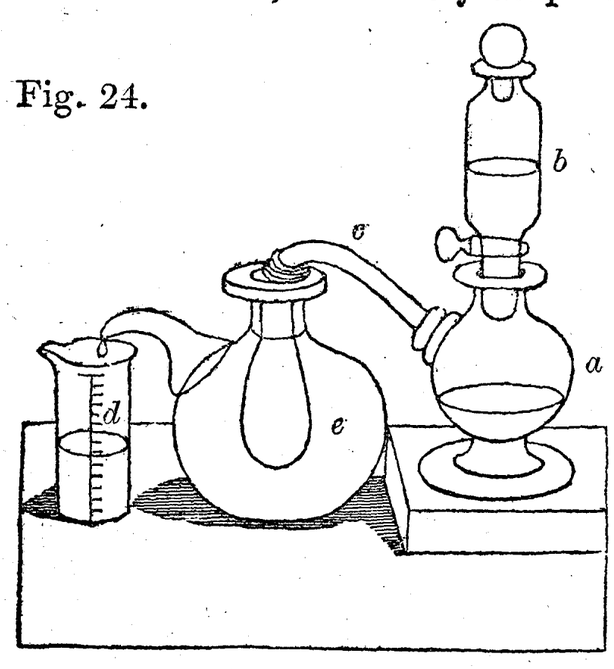
The remaining fluid must be boiled for a quarter of an hour, when the magnesia, if any exist, will be precipitated from it, combined with carbonic acid, and its quantity is to be ascertained in the same manner as that of the carbonate of lime.

If any minute proportion of alumina should, from peculiar circumstances, be dissolved by the acid, it will be found in the precipitate with the carbonate of lime, and it may be separated from it by boiling it for a few minutes with soap lye, sufficient to cover the solid matter; this substance dissolves alumina, without acting upon carbonate of lime.

Should the finely divided soil be sufficiently calcareous to effervesce very strongly with acids, a very simple method may be adopted for ascertaining the quantity of carbonate of lime, and one sufficiently accurate in all common cases.

Carbonate of lime, in all its states, contains a determinate proportion of carbonic acid, *i. e.* nearly 43 per cent., so that when the quantity of this elastic fluid, given out by any soil during the solution of its calcareous matter in an acid is known, either in weight or measure, the quantity of carbonate of lime may be easily discovered.

Fig. 24.



When the process by diminution of weight is employed, two parts of the acid and one part of the matter of the soil must be weighed in two separate bottles, and very slowly mixed together till the effervescence ceases; the difference between their weight, before and after the experiment, denotes the quantity of carbonic acid lost; for every four grains and a quarter of which, ten grains of carbonate of lime must be estimated.

The best method of collecting the carbonic acid, so as to discover its volume, is by a peculiar pneumatic apparatus,* in which its bulk may be measured by the quantity of water it displaces.

* Fig. 24, *a*, *b*, *c*, *d*, *e*, represent the different parts of this apparatus; *a* represents the bottle for receiving the soil; *b*, the bottle containing the acid, furnished with a stop-cock; *c*, the tube connected with a flaccid bladder; *d*, the graduated measure; *e*, the bottle for containing the bladder. When this instrument is used, a given quantity of soil is introduced into *a*; *b* is filled with muriatic acid diluted with an equal quantity of water; and the stop-cock being closed, is connected with the upper orifice of *a*, which is ground to receive it. The tube *c* is introduced into the lower orifice of *a*, and the bladder connected with it placed

6. After the calcareous part of the soil has been acted upon by muriatic acid, the next process is to ascertain the quantity of finely divided insoluble animal and vegetable matter that it contains.

This may be done with sufficient precision, by strongly igniting it in a crucible over a common fire, till no blackness remains in the mass. It should be often stirred with a metallic rod, so as to expose new surfaces continually to the air; the loss of weight that it undergoes denotes the quantity of the substance that it contains destructible by fire and air.

It is not possible, without very refined and difficult experiments, to ascertain whether this substance is wholly animal or vegetable matter, or a mixture of both. When the smell emitted during the incineration is similar to that of burnt feathers, it is a certain indication of some substance either animal or analogous to animal matter; and a copious blue flame at the time of ignition, almost always denotes a considerable proportion of vegetable matter. In cases when it is necessary that the experiment should be very quickly performed, the destruction of the decomposable substances may be assisted by the agency of nitrate of ammonia, which at the time of ignition may be thrown gradually upon the heated mass in the quantity of twenty grains for every hundred of residual soil. It accelerates the dissipation of the animal and vegetable matter, which it causes to be converted into elastic fluids; and it is itself at the same time decomposed and lost.

7. The substances remaining after the destruction of the vegetable and animal matter, are generally minute particles of earthy matter, containing usually alumina and silica, with combined oxide of iron or of manganesum.

To separate these from each other, the solid matter should be boiled for two or three hours with sulphuric acid, diluted with four times its weight of water; the quantity of the acid should be regulated by the quantity of solid residuum to be acted on, allowing for every hundred grains, two drachms or one hundred and twenty grains of acid.

The substance remaining after the action of the acid, may be considered as siliceous; and it must be separated and its weight ascertained, after washing and drying in the usual manner.

The alumina and the oxide of iron and manganesum, if any exist, are all dissolved by the sulphuric acid; they may be separated by succinate of ammonia, added to excess; which throws down the oxide of iron, and by soap lye, which will dissolve the alumina, but not the oxide of manganesum; the weights of the oxides ascertained after they have been heated to redness will denote their quantities.

Should any magnesia and lime have escaped solution in the muriatic acid, they will be found in the sulphuric acid; this, however, is rarely the case; but the process for detecting them, and ascertaining their quantities, is the same in both instances.

The method of analysis by sulphuric acid, is sufficiently precise for all

in its flaccid state into *e*, which is filled with water. The graduated measure is placed under the tube of *e*. When the stop-cock of *b* is turned, the acid flows into *a*, and acts upon the soil; the elastic fluid generated passes through *c* into the bladder, and displaces a quantity of water in *e* equal to it in bulk, and this water flows through the tube into the graduated measure: and gives by its volume the indication of the proportion of carbonic acid disengaged from the soil; for every ounce measure of which two grains of carbonate of lime may be estimated.—D.

usual experiments; but if very great accuracy be an object, dry carbonate of potassa must be employed as the agent, and the residuum of the incineration (6) must be heated red for a half hour, with four times its weight of this substance, in a crucible of silver or of well baked porcelain. The mass obtained must be dissolved in muriatic acid, and the solution evaporated till it is nearly solid; distilled water must then be added, by which the oxide of iron and all the earths, except silica, will be dissolved in combination as muriates. The silica, after the usual process of lixiviation, must be heated red; the other substances may be separated in the same manner as from the muriatic and sulphuric solutions.

This process is the one usually employed by chemical philosophers for the analysis of stones.

8. If any saline matter, or soluble vegetable or animal matter is suspected in the soil, it will be found in the water of lixiviation used for separating the sand.

This water must be evaporated to dryness in a proper dish, at a heat below its boiling point.

If the solid matter obtained is of a brown colour and inflammable, it may be considered as partly vegetable extract. If its smell, when exposed to heat, be like that of burnt feathers, it contains animal or albuminous matter; if it be white, crystalline, and not destructible by heat, it may be considered as principally saline matter; the nature of which may be known by the tests described page 64.

9. Should sulphate or phosphate of lime be suspected in the entire soil, the detection of them requires a particular process upon it. A given weight of it, for instance four hundred grains, must be heated red for half an hour in a crucible, mixed with one-third of powdered charcoal. The mixture must be boiled for a quarter of an hour, in a half pint of water, and the fluid collected through the filter, and exposed for some days to the atmosphere in an open vessel. If any notable quantity of sulphate of lime (gypsum) existed in the soil, a white precipitate will gradually form in the fluid, and the weight of it will indicate the proportion.

Phosphate of lime, if any exist, may be separated from the soil after the process for gypsum. Muriatic acid must be digested upon the soil, in quantity more than sufficient to saturate the soluble earths; the solution must be evaporated, and water poured upon the solid matter. This fluid will dissolve the compounds of earths with the muriatic acid, and leave the phosphate of lime untouched.

It would not fall within the limits assigned to this Lecture, to detail any processes for the detection of substances which may be accidentally mixed with the matters of soils. Other earths and metallic oxides are now and then found in them, but in quantities too minute to bear any relation to fertility or barrenness, and the search for them would make the analysis much more complicated without rendering it more useful.

10 When the examination of a soil is completed, the products should be numerically arranged, and their quantities added together, and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. It must, however, be noticed, that when phosphate or sulphate of lime is discovered by the independent process just described, (9,) a correction must be made for the general process, by subtracting a sum equal to their weight from the quantity of carbonate of lime, obtained by precipitation, from the muriatic acid.

In arranging the products, the form should be in the order of the experiments by which they were procured.

Thus, I obtained from 400 grains of a good siliceous sandy soil, from a hop garden near Tunbridge, Kent:—

		Grains.
Of Water of absorption		19
.. Loose stones and gravel, principally siliceous		53
.. Undecompounded vegetable fibres		14
.. Fine siliceous sand		212
Of minutely divided matter, separated by agitation and filtration, and consisting of		
Carbonate of lime	19	
Carbonate of Magnesia	3	
Matter destructible by heat, principally vegetable	15	
Silica	21	
Alumina	13	
Oxide of iron	5	
Soluble matter, principally common salt and vegetable extract	3	
Gypsum	2	
		81
Amount of all the products		379
Loss		21

The Loss in this analysis is not more than usually occurs, and it depends upon the impossibility of collecting the whole quantities of the different precipitates; and upon the presence of more moisture than is accounted for in the water of absorption, and which is lost in the different processes.

When the experimenter is become acquainted with the use of the different instruments, the properties of the reagents, and the relations between the external and chemical qualities of soils, he will seldom find it necessary to perform, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid (7) may be omitted. In examining peat soils, he will principally have to attend to the operation by fire and air (8); and in the analysis of chalks and loams, he will often be able to omit the experiment by sulphuric acid (9).

In the first trials that are made by persons unacquainted with chemistry, they must not expect much precision of result. Many difficulties will be met with: but, in overcoming them, the most useful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science, as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information; but perhaps there is no better mode of gaining it, than that of attempting original investigations. In pursuing his experiments, he will be continually obliged to learn the properties of the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operations, and acquired for the purpose of discovery.

Plants being possessed of no locomotive powers, can grow only in places where they are supplied with food; and the soil is necessary to their existence, both as affording them nourishment, and enabling them to fix themselves in such a manner as to obey those mechanical laws by which their radicles are kept below the surface, and their leaves exposed to the free atmosphere. As the systems of roots, branches, and leaves are very different in different vegetables, so they flourish most in different soils:

the plants that have bulbous roots require a looser and a lighter soil than such as have fibrous roots; and the plants possessing only short fibrous radicles demand a firmer soil than such as have tap roots, or extensive lateral roots. *

A good turnip soil, from Holkham, Norfolk, afforded me 8 parts out of 9 siliceous sand; and the finely divided matter consisted

Of Carbonate of lime	63
.. Silica	15
.. Alumina	11
.. Oxide of iron	3
.. Vegetable and saline matter	5
.. Moisture	3

I found the soil taken from a field at Sheffield-place, in Sussex, remarkable for producing flourishing oaks, to consist of six parts of sand, and one part of clay and finely divided matter. And one hundred parts of the entire soil, submitted to analysis produced,

	Parts.
Silica	54
Alumina	28
Carbonate of lime	3
Oxide of iron	5
Decomposing vegetable matter	4
Moisture and loss	3

An excellent wheat soil, from the neighbourhood of West Drayton, Middlesex, gave three parts in 5 of siliceous sand; and the finely divided matter consisted of

Carbonate of lime	28
Silica	32
Alumina	29
Animal or vegetable matter and moisture	11

Of these soils the last was by far the most, and the first the least, coherent in texture. In all cases the constituent parts of the soil which give tenacity and coherence are the finely divided matters; and they possess the power of giving those qualities in the highest degree when they contain much alumina. A small quantity of finely divided mntter is suf-

* Such plants as the potato, the turnip, the beet, &c., are found not to thrive well in stiff aluminous soils, and so generally has this been remarked, that the free and porous soils, adapted to their culture, are designated Turnip Soils, while the stiff aluminous ones are termed Wheat Soils. Several circumstances require to be kept in view in explaining the difference. In stiff clay soils there is less free access of air and water, and consequently a slower decomposition of manure and accumulated organic matter. Now, it is known that the plants above mentioned, although capable of drawing largely on the air, require a very abundant supply of carbonic acid from manures while they are no less dependent on inorganic matter than grain crops. Again, stiff aluminous soils, although remarkably well adapted to afford the mechanical support required by strong and tall plants, as wheat, are by so much the less fitted to yield, and afford room to a fleshy root or tuber, that swells much as it grows. The texture of a soil, therefore, is of much importance, independently of the inorganic substances capable of being afforded to plants, a circumstance consistent with the analysis in the text, and with the fact that wheat soils have often been rendered capable of producing turnips by being thorough-drained, or by being mixed with siliceous sand and gravel.

ficient to fit a soil for the production of turnips and barley; and I have seen a tolerable crop of turnips on a soil containing 11 parts out of 12 sand.* A much greater proportion of sand, however, always produces absolute sterility. The soil of Bagshot heath, which is entirely devoid of vegetable covering, contains less than $\frac{1}{20}$ of finely divided matter. 400 parts of it, which had been heated red, afforded me 380 parts of coarse siliceous sand; 9 parts of fine siliceous sand, and 11 parts of impalpable matter, which was a mixture of ferruginous clay, with carbonate of lime. Vegetable or animal matters, when finely divided, not only give coherence, but likewise softness and penetrability; but neither they nor any other part of the soil must be in too great proportion; and a soil is unproductive if it consist entirely of impalpable matters. †

Pure alumina or silica, pure carbonate of lime, or carbonate of magnesia, are incapable of supporting healthy vegetation.

No soil is fertile that contains as much as 19 parts out of 20 of any of the constituents that have been mentioned.

It will be asked, are the pure earths in the soil merely active as mechanical or indirect chemical agents, or do they actually afford food to the plant? This is an important question; and not difficult of solution.

* Turnips and rye may be grown on soils so loose and sandy that barley cannot be grown with advantage. There are many districts where the suitability of rye to light soils appears to be unknown, or at least, it is not acted on.

† The most common examples of soils of this description are impalpable clays, partially reclaimed peat, and soils, which from their vicinity to sources of very rich manures, have become too light and friable.

Of the first, or impalpable clays, incidental mention has already been made. They occur chiefly in flat low-lying districts, and are always transported (*alluvial* or *diluvial*). These clays are infertile, not so much from the want of any particular chemical constituents, as from the want of a proper mechanical texture. They are laboured at greater expense than any other soils, and unless they are opened up and ameliorated by complete drainage, or admixture of sand or grit, fallow crops cannot be cultivated to advantage, and the expensive system of naked fallowing cannot be dispensed with.

Partially reclaimed peat soils occur very frequently in Scotland and Ireland, more rarely in England. When inquiry is made into the history and treatment of these infertile soils, it is frequently found, that at first, they have been partially drained and fully limed, that to defray the expense of these operations, several successive crops of oats have been reaped, which proved richer in straw than grain, that subsequently oats could not be grown to profit, and that when laid down in pasture, the rye-grass and clover disappeared, and were replaced by the small sorrel (*Rumex Acetosella*).

The impropriety of overcropping any soil, more especially one consisting almost exclusively of inert organic matter, is obvious. The methods which have been found most effectual in restoring such soils, are to complete the drainage and to dress with clay and sand, or gravel. Calcareous sand, when it can be obtained, deserves a preference over siliceous sand.

The last of the instances—that in which soils have become too light and friable from the continued application of rich manures, occurs but rarely, chiefly on the coast, near Fishing Villages, or in the vicinity of large towns. These soils continue capable of producing green crops, after they have ceased to grow grass and white crops. When crops of the latter kind are sown in them the plants spring up, but fail to attain maturity. The cause is partly mechanical, the throwing out by the frost, and the withering influence of drought on the porous soil, and partly chemical, the exhaustion of certain inorganic constituents from excessive supply of azotised matters. Remedies that never fail to cure the evil are dressing with clay and deep ploughing.

The earths consist, as I have before stated, of metals united to oxygen; and these metals have not been decomposed; there is, consequently, no reason to suppose that the earths are convertible into the elements of organized compounds, into carbon, hydrogen, and azote.

Plants have been made to grow in given quantities of earth. They consume very small portions only; and what is lost may be accounted for by the quantities found in their ashes; that is to say, it has not been converted into any new products.

The carbonic acid united to lime or magnesia, if any stronger acid happens to be formed in the soil during the fermentation of vegetable matter which will disengage it from the earths, may be decomposed: but the earths themselves cannot be supposed convertible into other substances, by any process taking place in the soil.

In all cases the ashes of plants contain some of the earths of the soil in which they grow; but these earths as may be seen from the table of the ashes afforded by different plants, given in the last Lecture, never equal more than $\frac{1}{50}$ of the weight of the plant consumed.

If they be considered as necessary to the vegetable, it is as giving hardness and firmness to its organization. Thus, it has been mentioned that wheat, oats, and many of the hollow grasses, have an epidermis, principally of siliceous earth; the use of which seems to be to strengthen them, and defend them from the attacks of insects and parasitical plants. *

* Of the newer chemical doctrines applicable to agriculture, none is more important or likely to engross a greater share of attention, than the inorganic constituents of plants. The largest contribution to this department of science which had been made at the time of the publication of the text, was that of Saussure, (see page 65,) but since that time various analyses by Sprengel, Berthier, Boussingault, and others, bearing more or less directly on the subject, have appeared. The application of the subject, and the full estimate of its practical importance, is undoubtedly due to Liebig, and it forms a very prominent feature in his admirable treatise so frequently referred to.

Of the earths properly so called, silicic acid occurs most frequently. It has already been noticed that it occurs in considerable quantity in the epidermis of many plants, particularly *Gramineæ, Equisetaceæ,* &c. Silicic acid also occurs in all kinds of charcoal, and hence ought to be regarded as a constituent—a small one indeed—but still a constituent of wood. Liebig considers that "silicic acid is the first solid substance taken up by plants; it appears to be the material from which the formation of wood takes its origin, acting like a grain of sand around which the crystals form in a solution of a salt which is in the act of crystallising. Silicic acid appears to perform the function of woody fibre in the *Equisetaceæ* and bamboos, just as the crystalline salt, oxalate of lime, does in many of the lichens."

Silicic acid being quite insoluble in water, unless when combined with an alkali, and being actually found in straw combined with potash, it may be inferred that alkalies are the means by which this most important substance is rendered available to growing plants.

Of the alkaline earths, lime and magnesia occur in considerable quantity in many plants, partly in combination with organic acids, and partly with inorganic acids. Hence carbonate of lime and magnesia, together with sulphate of lime and phosphates of lime and magnesia, are found in their ashes. Sulphate of lime, and indeed calcareous soils generally, are found highly favourable to the growth of clover, peas, beans, and other *Leguminosæ;* a fact borne out by the analysis of the ashes of these plants.

It has been remarked that the more farinaceous sorts of peas termed *boilers,* are produced on the less calcareous soils, and contain less lime. This, however, is quite consistent with the general fact that leguminous plants contain lime, for

Many soils are popularly distinguished as *cold;* aud the distinction, though at first view it may appear to be founded on prejudice, is really just.

Some soils are much more heated by the rays of the sun, all other circumstances being equal, than others; and soils brought to the same degree of heat cool in different times, *i.e.* some cool much faster than others.

when freely supplied with that earth, the produce is greater and the plants more vigorous, although the seeds are harder and less mealy; just as the driest and most farinaceous potatoes, such as the small stock occasionally raised by farmers, not for profit but for their own tables, are grown on land broken up from lea, and not otherwise manured than by the vegetable matter which has accumulated in it during its continuance in pasture, while the potatoes produced for the market, and of which as large a return as possible must be secured, are grown after the white crop which properly succeeds the lea, and are manured as highly as the turnips, and hence are often more or less watery or waxy.

Earthy phosphates occur in seeds, particularly in those of the cereals wheat, barley, oats, rye-grass, &c., and in smaller quantity in the straw of these plants, (see table, page 65). Thus while the ashes of the seeds of wheat gave 44·5 per cent, of earthy phosphates, the ashes of wheat straw gave only 6·2 per cent.

The alkalies potash and soda, particularly the former, are constantly present in plants. Indeed the great supply of pot and pearl ashes comes from countries where wood abounds. Potash is obtained by burning the superfluous timber, lixiviating the ashes, and evaporating the solution to dryness; soda is prepared from marine and littoral plants by a similar process. All kinds of charcoal contain carbonate of potash, indicating that the alkali is an essential constituent combined with organic acids. In addition to the carbonate of potash contained in the ashes, other compounds of potash with inorganic acids occur, although in smaller quantity. Alkalies, therefore, must be considered essential constituents of all plants, and hence also of all fertile soils and useful manures.

The quantity of alkali afforded by different plants is extremely various. Herbaceous plants contain larger quantities than those that have woody stems, and leaves and twigs of trees contain it in much greater quantity than the wood. It is well known that the fronds of the fern, (*Pteris aquilina,*) the stems and leaves of the potato, the leaves of the turnip, the plant of the wormwood, and all the weeds of cultivated land, afford potash in considerable quantity, and yet in many places potatoe halm and turnip tops are allowed to go to waste in place of being ploughed in in a recent state, to decay and contribute this most necessary aliment to the succeeding white crop.

Liebig suggests that it may possibly be found that each species of plant requires a certain fixed amount of alkaline matter, as the alkaline matter obviously regulates the production of organic acids, and that the particular alkali will be dependent on the resources of the soil. In support of this view, he adduces two cases of plants grown on different soils, where although the amount of ashes differed, the neutralizing power of the bases, or what amounts to the same, the quantity of oxygen in the bases found in the ashes as carbonates, was equal.

The first case consists of two analyses of the ashes of the pine tree by Saussure. One of the pines grew on Mont Breven, 100 parts of its ashes gave 56·71 of carbonates. The individual bases were lime, magnesia, and potash, and the oxygen due to these was 9·01. The other was a pine, grown on Mont la Salle. The sum of its carbonates was 58·55, the bases were lime and potash, no magnesia being present, and the oxygen due to the bases was 8·95. But the numbers 9.01, and 8·95, are as nearly identical as could be looked for in two analyses of the same thing.

The second case adduced by Liebig embraces two analyses of the ashes of firwood by Berthier, the one a fir grown in Allevard, the other in Norway. The first of these contained lime, potash, soda, and magnesia, and the oxygen due to as much of these bases as had been combined with organic acids was 11·62. The ashes of the Norwegian fir contained the same bases, although in different pro-

This property has been very little attended to in a philosophical point of view; yet it is of the highest importance in agriculture. In general, soils that consist principally of a stiff white clay are difficultly heated; and being usually very moist, they retain their heat only for a short time. *Chalks* are similar in one respect, that they are difficultly heated; but being drier they retain their heat longer, less being consumed in causing the evaporation of their moisture. *

portions, and the oxygen due to the portion that had in the wood been combined with organic acids was 11·47. Now the difference between the oxygen of the two is only ·15, a still closer coincidence than in the former case.

Should these remarkable results be confirmed, it follows that alkaline matter in definite quantity, is absolutely necessary; that one base can substitute or take the place of another; that where alkaline constituents, in insufficient quantity, are present in a soil, no manures, in which these are awanting, however rich in other constituents, can be beneficial, on the contrary, they must make matters worse, by facilitating the exhaustion of alkaline bases; and that the geological history of soils, and the determination of the minerals by whose decomposition they are produced, is a matter of far greater importance than was believed prior to the publication of Liebig's views.

It ought to be admitted that the plants cultivated in our fields are not in their natural state, and that further investigation is necessary before it is concluded that they are regulated by exactly the same laws as wild plants; still the doctrine would so satisfactorily explain many anomalies familiar to practical agriculturists, that it is difficult to resist the assumption. Certainly, no investigation is more worthy of the attention of competent chemists. From the remarks already made regarding the qualities of peas and potatoes, cultivated according to different methods, it would appear that an examination of the inorganic constituents of these crops would be likely to throw much light on the subject.

The doctrine of substitution is illustrated and strengthened by several facts previously well known, but never explained on any philosophical principle, till Liebig brought forward the doctrine and applied it to them. [Chemistry applied to Agriculture, 2d edition, page 98, *et seq.*]

Thus the organic alkali *Solanin* which gives the poisonous property to potatoes grown without soil, would appear to be formed for the purpose of replacing the potash required by the healthy plant.

Littoral plants, containing soda, can be grown, for a certain time at least, in soils affording only potash, and that base is found in their ashes.

In opium, (the inspissated juice of the poppy,) the organic acid is generally a peculiar one, called *mechonic;* but sometimes this acid is awanting, its place having been taken by sulphuric acid. Several organic bases are found in opium, the most important are *morphia* and *narcotina*. The proportions of these vary, but an increase of the one always corresponds to a diminution of the other.

Lastly, in *cinchona* bark, the organic acid is uniformly the *kinic*, while the bases are *quina, cinchonia,* and *lime*. Now it is found that all the three bases vary much in proportion, but manufacturers of quina know that unprofitable barks have the lime in excess, and profitable ones the organic alkalies.

A little consideration of this doctrine will suffice to convince any one of its importance in directing a number of points connected with ordinary culture, to say nothing of that vast, though almost untouched field—the cultivation of plants for pharmaceutic purposes.

* Chalks form remarkably dry soils on account of the porous nature of the rock. De la Beche well remarks to have seen "parts of a table-land, formed of a fair though gravely soil, resting on a tenaceous clay, drained naturally by means of pinnacles of chalk, which pierced through the clay in several places and entered the gravelly soil above. The portions of the soil above and near the chalk pinnacles being kept fairly drained by the well known property of the chalk readily to absorb moisture, while the portions of the soil which were too far from the draining influence of the pinnacles, were wet and heavy."

A black soil, containing much soft vegetable matter, is most heated by the sun and air; and the coloured soils, and the soils eontaining much carbonaceous matter, or ferruginous matter, exposed under equal circumstances to sun, acquire a much higher temperature than pale-coloured soils.

When soils are perfectly dry, those that most readily become heated by the solar rays likewise cool most rapidly; but I have ascertained by experiment, that the darkest coloured dry soil (that which contains abundance of animal or vegetable matter: substances which most facilitate the diminution of temperature,) when heated to the same degree, provided it be within the common limits of the effect of solar heat, will cool more slowly than a wet pale soil, entirely composed of earthy matter.

I found that a rich black mould, which contained nearly $\frac{1}{4}$ of vegetable matter, had its temperature increased in an hour from 65° to 88° by exposure to sunshine; whilst a chalk soil was heated only to 69° under the same circumstances. But the mould removed into the shade, where the temperature was 62°, lost, in half an hour, 15°; whereas the chalk, under the same circumstances, had lost only 4°.

A brown fertile soil, and a cold barren clay were each artificially heated to 88°, having been previously dried: they were then exposed in a temperature of 57°; in half an hour the dark soil was found to have lost 9° of heat; the clay had lost only 6°. An equal portion of the clay containing moisture, after being heated to 88°, was exposed in a temperature of 55°; in less than a quarter of an hour it was found to have gained the temperature of the room. The soils in all these experiments were placed in small tin-plate trays two inches square, and half an inch in depth; and the temperature ascertained by a delicate thermometer.*

* In connexion with these results regarding the heating and cooling of soils, it may be useful to notice some of the experiments of Edwards and Colin on the temperature that seeds can bear without destroying their vitality. For if in any country or locality, the influence of the sun, the angle at which the rays fall, the colour of the surface, and the other circumstances that regulate the temperature, be such that a seed is heated beyond its natural power of resistance, a limit is set to the cultivation of that particular plant.

Similar experiments are also calculated to shew the way in which seeds can be most safely conveyed from a temperate or cold climate in one hemisphere, to a corresponding one in the other—a matter of much importance to those who would add to the number of our useful and ornamental plants:—

1st, In contact with water, wheat, barley, rye, beans and flax, were killed, or rendered incapable of vegetating when afterwards sown in favourable circumstances, by exposure for 27·5 minutes to a temperature of 143·6° F.

Barley and flax were killed by exposure to 125·6° F., while the others were not injured by this temperature.

2d. In watery vapour, exposure for 15 minutes, at a temperature of 167°, destroyed vitality, while a similar exposure at 143° did not prove hurtful.

3d. In dry air, at 167°, most of the seeds escaped unhurt.

4th. Wheat, rye, and barley, were exposed in contact with water to a temperature of 95° for three days; all the barley and the greater part of the wheat and rye were found to be destroyed.

At the season of the year when the cereals and legumes are sown, it is certain that in a climate like ours, the soils most easily heated do not reach a temperature that would injure the seeds sown in them; it is not however equally certain that turnip seeds, and particularly potato *sets*, are in every instance exempt from injury from this cause.

The greatest effect of the sun's rays observed by Schübler on the surface of a blackish-grey garden mould on which he experimented at Tübingen, was on the 16th June 1828, when a thermometer, whose bulb was covered with the

Nothing can be more evident, than that the genial heat of the soil, particularly in spring, must be of the highest importance to the rising plant. And when the leaves are fully developed, the ground is shaded; and any injurious influence, which in the summer might be expected from too great a heat, entirely prevented; so that the temperature of the surface, when bare and exposed to the rays of the sun, affords at least one indication of the degree of its fertility; and the thermometer may be sometimes a useful instrument to the purchaser or improver of lands.

The moisture in the soil influences its temperature; and the manner in which it is distributed through, or combined with, the earthy materials, is of great importance in relation to the nutriment of the plant. If water is too strongly attracted by the earths, it will not be absorbed by the roots of the plants; if it is in too great quantity, or too loosely united to them, it tends to injure or destroy the fibrous parts of the roots.

There are two states in which water seems to exist in the earths, and in animal and vegetable substances: in the first state it is united by chemical, in the other by cohesive, attraction.

If pure solution of ammonia, or potassa, be poured into a solution of alum, alumina falls down combined with water; and the powder dried by exposure to air will afford more than half its weight of water by distillation; in this instance the water is united by chemical attraction. The moisture which wood, or muscular fibre, or gum, that have been heated to 212°, afford, by distillation, at a red heat, is likewise water, the elements of which were united in the substance by chemical combination.

When pipe-clay dried at the temperature of the atmosphere is brought in contact with water, the fluid is rapidly absorbed: this is owing to cohesive attraction. Soils in general, vegetable and animal substances, that have been dried at a heat below that of boiling water, increase in weight by exposure to air, owing to their absorbing water existing in the state of vapour in the air, in consequence of cohesive attraction.

The water *chemically combined* amongst the elements of soils, unless in the case of the decomposition of animal or vegetable substances, cannot be absorbed by the roots of plants; but that *adhering* to the parts of the soil is in constant use in vegetation. Indeed there are few mixtures of the earths, found in soils, that contain any chemically combined water; water is expelled from the earths by most substances that combine with them. Thus, if a combination of lime and water be exposed to carbonic acid, the carbonic acid takes the place of water: and compounds of alumina and silica, or other compounds of the earths, do not chemically unite with water: and soils, as it has been stated, are formed either by earthy carbonates, or compounds of the pure earths and metallic oxides.

When saline substances exist in soils, they may be united to water both chemically and mechanically; but they are always in too small a quantity to influence materially the relations of the soil to water.

The power of the soil to absorb water by cohesive attraction, depends in great measure upon the state of division of its parts; the more divided they are, the greater is their absorbent power. The different constituent parts of soils likewise appear to act, even by cohesive attraction, with different degrees of energy. Thus vegetable substances seem to be more absorbent than animal substances; animal substances more so than compounds of alumina and silica; and compounds of alumina and silica more absorbent than carbonates of lime and magnesia: these differences may,

mould to the depth of a line, rose at noon to 153·5 F., while the temperature of the air in the shade was 78°.

however, possibly depend upon the differences in their state of division, and upon the surface exposed.

The power of soils to absorb water from air, is much connected with fertility. When this power is great, the plant is supplied with moisture in dry seasons; and the effect of evaporation in the day is counteracted by the absorption of aqueous vapour from the atmosphere, by the interior parts of the soil during the day, and by both the exterior and interior during night.

The stiff clays approaching to pipe clays in their nature, which take up the greatest quantity of water when it is poured upon them in a fluid form, are not the soils which absorb most moisture from the atmosphere in dry weather. They cake, and present only a small surface to the air; and the vegetation on them is generally burnt up almost as readily as on sands.

The soils that are most efficient in supplying the plant with water by atmosheric absorption, are those in which there is a due mixture of sand, finely divided clay, and carbonate of lime, with some animal or vegetable matter; and which are so loose and light as to be freely permeable to the atmosphere. With respect to this quality, carbonate of lime and animal and vegetable matter, are of great use in soils; they give absorbent power to the soil without giving it likewise tenacity: sand, which also destroys tenacity, on the contrary, gives little absorbent power.

I have compared the absorbent powers of many soils with respect to atmospheric moisture, and I have always found it greatest in the most fertile soils; so that it affords one method of judging of the productiveness of land.*

* A convenient way of conducting such experiments, is to dry a quantity of the soil by exposing it in a flat shallow capsule of platinum or glazed porcelain to a temperature of 150° till it ceases to lose weight, to cover the capsule closely till cold, and counterpoise it and its contents. The capsule containing the soil evenly spread in it is set on a stand placed in a large flat vessel containing some water, and over it is placed a bell jar, or air pump receiver, with its mouth resting in the water. After standing as long as the operator considers necessary, the capsule is removed and weighed quickly, that no loss may take place by evaporation. The temperature of the apartment in which the experiment is conducted should remain uniform, and the air should not be unnecessarily dry. The increase in weight indicates the quantity of water absorbed.

It may be interesting to compare the following Table from Schübler, (Journal of the English Agricultural Society, Vol. I., page 196) with the results given in the text:—

Kinds of Earth.	1000 grains of earth, spread on a surface of 50 square inches, absorbed in			
	12 Hours.	24 Hours.	48 Hours.	72 Hours.
	Grains.	Grains.	Grains.	Grains
Siliceous sand,	0	0	0	0
Calcareous sand,	2	3	3	3
Gypsum powder,	1	1	1	1
Sandy clay,	21	26	28	28
Loamy clay,	25	30	34	35
Stiff clay,	30	36	40	41
Grey pure clay,	37	42	48	49
Fine carbonate of lime.	26	31	35	35
Fine carbonate of magnesia,	69	76	80	82
Humus,	80	97	110	120
Garden mould,	35	45	50	52
Arable soil.	16	22	23	23
Slaty marl,	24	29	32	33

1000 parts of a celebrated soil from Ormiston in East Lothian, which contained more than half its weight of finely divided matter, of which 11 parts were carbonate of lime, and 9 parts vegetable matter, when dried at 212°, gained in an hour by exposure to air saturated with moisture, at temperature 62°, 18 grains.

1000 parts of a very fertile soil from the banks of the river Parret, in Somersetshire, under the same circumstances, gained 16 grains.

1000 parts of a soil from Mersea, in Essex, worth 45 shillings an acre, gained 13 grains.

1000 grains of a fine sand from Essex, worth 28 shillings an acre, gained 11 grains.

1000 of a coarse sand worth 15 shillings an acre, gained only 8 grains.

1000 of the soil of Bagshot-heath gained only 3 grains.

Water, and the decomposing animal and vegetable matter existing in the soil, constitute the true nourishment of plants: and as the earthy parts of the soil are useful in retaining water, so as to supply it in the proper proportions to the roots of the vegetables, so they are likewise efficacious in producing the proper distribution of the animal or vegetable matter; when equally mixed with it they prevent it from decomposing too rapidly; and by their means the soluble parts are supplied in proper proportions.

Besides this agency, which may be considered as mechanical, there is another agency between soils and organizable matters, which may be regarded as chemical in its nature. The earths, and even the earthy carbonates, have a certain degree of chemical attraction for many of the principles of vegetable and animal substances. This is easily exemplied in the instance of alumina and oil; if an acid solution of alumina be mixed with a solution of soap, which consists of oily matter and potassa; the oil and the alumina will unite and form a white powder, which will sink to the bottom of the fluid.

The extract from decomposing vegetable matter when boiled with pipe-clay or chalk, forms a combination by which the vegetable matter is rendered more difficult of decomposition and of solution. Pure silica and siliceous sands have little action of this kind; and the soils which contain the most alumina and carbonate of lime, are those which act with the greatest chemical energy in preserving manures.* Such soils merit the appellation

While it must be admitted that this property of absorbing moisture from the air, possessed by soils containing alumina and decaying organic matter, is an important means of supplying water and gaseous matter to plants in dry seasons, there is reason to fear that these tables lead us to estimate it at more than its real value. It is only in extremely dry weather, and to a very trifling depth, that the soil in our fields ever gets so dry as to admit of this action to any very considerable extent. Soils naturally of good texture, or that have been rendered so by thorough draining and subsoiling, are capable of retaining much water in their pores in no objectionable form. The heat applied at the surface sublimes this water about, and while part escapes, its place is readily supplied by water which is derived from below, out of the open subsoil. It is from this source then, that these soils are rendered more able to resist dry weather than compact, undrained, inorganic soils. A few experiments with moist soils, in appropriate glass vessels, will do more to satisfy any one on this subject, than reasoning apart from actual trials.

* The slow decomposition of manure in aluminous soils, appears to be chiefly due to the closeness of their texture, and the consequent difficulty with which air and water find access to them. In calcareous soils, manure is found not

which is commonly given to them of rich soils; for the vegetable nourishment is long preserved in them, unless taken up by the organs of plants. Siliceous sands, on the contrary, deserve the term hungry, which is commonly applied to them; for the vegetable and animal matters they contain not being attracted by the earthy constituent parts of the soil, are more liable to be decomposed by the action of the atmosphere, or carried off from them by water.

In most of the black and brown rich vegetable moulds, the earths seem to be in combination with a peculiar extractive matter, afforded during the decomposition of vegetables: this is slowly taken up, or attracted from the earths by water, and appears to constitute a prime cause of the fertility of the soil.*

The standard of fertility of soils for different plants must vary with the climate; and must be particularly influenced by the quantity of rain.

The power of soils to absorb moisture ought to be much greater in warm or dry counties, than in cold and moist ones; and the quantity of clay, or vegetable or animal matter they contain greater. Soils also on declivities ought to be more absorbent than in plains or in the bottom of valleys. Their productiveness likewise is influenced by the nature of the subsoil or the stratum on which they rest.

When soils are immediately situated upon a bed of rock or stone, they are much sooner rendered dry by evaporation, than where the subsoil is of clay or marl; and a prime cause of the great fertility of the land in the moist climate of Ireland, is the proximity of the rocky strata to the soil. †

nearly so lasting, unless indeed, as sometimes happens, they contain also a good deal of finely divided aluminous matter. It is, however, quite consistent with the best experiments, that alkaline bases promote the decomposition of organic matter. In sandy and gravelly soils, in like manner, the rapid consumption of manures, and the necessity of applying to them frequent small doses, in place of one large dose, during the rotation, seem to be explained most simply by their looser texture.

* Liebig has shewn that it is not soluble organic substances that constitute the proper food of plants. Organic matter decays by a peculiar process of slow oxidation, called by him *Eremacausis*. During this decay carbonic acid is evolved, and constitutes, along with the carbonic acid derived from the air, the principal part of the food of plants. *Extractive* matter is capable of this sort of decay, and consequently of supplying carbon to plants, but *as* extractive matter it is not capable of assimilation; it is a product of assimilation and cannot be regarded as forming directly the food of plants. [See notes to Lecture VI.]

† Rocks differ much in this respect. The principal circumstances demanding attention in speculating on this topic, are their *texture* and *inclination*. Chalk, siliceous sandstone, conglomerate and all porous rocks lying immediately under the soil, imbibe the surface water, and to some extent, when the soil itself is of suitable texture, supply the want of drains. During protracted drought, a portion of the water thus imbibed by the subjacent rock is again restored to the soil, and supplies the plants growing in it. Some of the most fertile soils in the country are thus situated.

When the subjacent rock is compact and impervious, as is the case with clays, shales, compact limestone, many slate-rocks, &c, the water, in winter, and during wet weather, finding no outlet, stagnates, and produces sour and spongy bogs, in which rushes and marsh plants make their appearance. During continued drought again, these soils become baked and parched in a remarkable manner.

The inclination of the strata is also important. Strata even of a close and compact texture, sometimes form a pretty good support for soil when they lie at a high angle, so that excess of water can percolate down between the layers. This high inclination is often met with in the rocks of the Grauwacke group,

A clayey subsoil will sometimes be of material advantage to a sandy soil; and in this case it will retain moisture in such a manner as to be capable of supplying that lost by the earth above, in consequence of evaporation, or the consumption of it by plants.

A sandy, or gravelly subsoil, often corrects the imperfections of too great a degree of absorbent power in the true soil.

In calcareous counties, where the surface is a species of marl, the soil is often found only a few inches above the limestone; and its fertility is not impaired by the proximity of the rock; though in a less absorbent soil, this situation would occasion barrenness; and the sandstone and limestone hills in Derbyshire and North Wales, may be easily distinguished at a distance in summer by the different tints of the vegetation. The grass on the sandstone hills usually appears brown and burnt up: that on the limestone hills, flourishing and green.

In devoting the different parts of an estate to the necessary crops, it is perfectly evident from what has been said, that no general principle can be laid down, except when all the circumstances of the nature, composition, and situation of the soil and subsoil are known.

The methods of cultivation likewise must be different for different soils. The same practice which will be excellent in one case may be destructive in another.

Deep ploughing may be a very profitable practice in a rich thick soil; and in a fertile shallow soil, situated upon cold clay or sandy subsoil, it may be extremely prejudicial. *

and among the non-fossiliferous slates. When impervious rocks lie horizontally there is no mitigation of the evils arising from excess of moisture, and *thorough* drainage is the only cure. Most soils indeed are capable of great improvement by drainage, but when this operation is gone about without any reference to the nature and properties of the subjacent layers, it is not wonderful that capital is often misapplied.

* Mistakes are sometimes committed regarding deep ploughing, trench-ploughing, and subsoil-ploughing, from inattention to a few simple principles.

Neither trench-ploughing, nor subsoil-ploughing, is admissible till complete drainage is provided. If the subsoil is gravelly or open, and merely wet from being capped by a layer of clay and oxide of iron, known in many localities as *pan*, or *iron-band*, draining may not be so much required, and subsoiling will be sufficient. The breaking up of the *pan* permits the free descent of the water, and the subsoil gradually becomes ameliorated, and admits of deep working, but not immediately. In most cases, however, the subsoil is more or less impervious and compact, and the treatment so successfully practised and advocated by Mr Smith, and popularly known as *Deanstonizing*, is by far the best mode of procedure. The frequent drains are first put in, the process of subsoiling follows, and after the subsoil has had time to become completely ameliorated, but not sooner, it may be advantageously mixed to some extent with the soil.

In some instances complete drainage has been immediately followed up by trench-ploughing, but unless in special cases this is objectionable. For the organic part of the soil is turned down, and an unoxidised and too inorganic and cold subsoil brought to the surface, to the injury of several of the crops, particularly the pasture.

The advantages of thorough draining and subsoiling are so generally acknowledged, that to say any thing of the manner in which the operations are performed is unnecessary, but a brief enumeration of the principal ways in which they act in improving land, may not be misplaced:—

1. Combined with the frequent drains, subsoiling loosens the stiff and impervious subsoil, and permits of the percolation of excess of surface water into the drains.

In a moist climate, where the quantity of rain that falls annually equals from 40 to 60 inches, as in Lancashire, Cornwall, and some parts of Ireland, a siliceous sandy soil is much more productive than in dry districts; and in such situations, wheat and beans will require a less coherent and absorbent soil than in drier situations; and plants having bulbous roots, will flourish in a soil containing as much as 14 parts out of 15 of sand.

Even the exhausting powers of crops will be influenced by like circumstances. In cases where plants cannot absorb sufficient moisture, they must take up more manure. And in Ireland, Cornwall, and the western Highlands of Scotland, corn will exhaust less than in dry inland situations. Oats, particularly in dry climates, are impoverishing in a much higher degree than in moist ones.

Soils appear to have been originally produced in consequence of the decomposition of rocks and strata. It often happens that soils are found in an unaltered state upon the rocks from which they were derived. It is easy to form an idea of the manner in which rocks are converted into soils, by referring to the instance of *soft granite*, or *porcelain granite*. This substance consists of three ingredients, quartz, felspar, and mica. The quartz is almost pure siliceous earth, in a crystalline form. The felspar and mica are very compounded substances; both contain silica, alumina, and oxide of iron; in the felspar there is usually lime and potassa; in the mica, lime and magnesia.

When a granitic rock of this kind has been long exposed to the influence of air and water, the lime and the potassa contained in its constituent parts are acted upon by water or carbonic acid; and the oxide of iron, which is almost always in its least oxidized state, tends to combine with

2. Any deleterious soluble substances contained in the soil or subsoil, are gradually carried off.

3. Free access of air and water is obtained, and steady decomposition, both of the organic and inorganic matters of the soil promoted, thereby securing a more abundant supply of food for plants.

4. The space to which the roots of plants obtain easy access is greatly increased, and these roots remaining, and after the death of the plants, decaying in the soil, increase its depth, and the proportion of humus.

5. The free admission of air gradually converts the injurious protoxide of iron, so characteristic of bad subsoils, into the useful peroxide found in fertile soils.

6. The subsoil thus gradually ameliorated becomes fit for being mixed with the soil, and of supplying mineral constituents, in which the soil itself may be deficient.

7. It might be supposed that a soil improved by these means would be more liable to suffer during protracted drought than an undrained one; this however is not the case, the plants being found fresh and vigorous, while those of a cold, compact, and undrained soil are burnt up. This arises from several causes—the improved texture and absorbent power—the greater depth and feeding surface afforded to the roots—and the facility with which water adheres in a state fit for nourishing the roots. When the excess of water gets readily down into the drains, that which adheres contains carbonic acid, oxygen, ammonia, and other necessary and alimentary substances; while the stagnant water of undrained soils is prejudicial, by excluding air, by keeping injurious dissolved substances in contact with the roots, and by the cold incident to excess of moisture.

It should also be noticed, that for a few years, either trench-ploughing, or subsoiling, has a tendency to render the crops later. This effect, however, is but temporary, and not to be thought of in comparison with the advantages of this great and fundamental improvement.

more oxygen; the consequence is, that the felspar decomposes, and likewise the mica: but the first the most rapidly. The felspar, which is as it were the cement of the stone, forms a fine clay: the mica partially decomposed mixes with it as sand; and the undecomposed quartz appears as gravel, or sand of different degrees of fineness. *

As soon as the smallest layer of earth is formed on the surface of a rock, the seeds of lichens, mosses, and other imperfect vegetables, which are constantly floating in the atmosphere, and which have made it their resting place, begin to vegetate; their death, decomposition, and decay, afford a certain quantity of organizable matter, which mixes with the earthy materials of the rock; in this improved soil more perfect plants are capable of subsisting; these in their turn absorb nourishment from water and the atmosphere; and after perishing, afford new materials to those already provided: the decomposition of the rock still continues; and at length by such slow and gradual processes, a soil is formed in which even forest trees can fix their roots, and which is fitted to reward the labours of the cultivator.

In instances where successive generations of vegetables have grown upon a soil, unless part of their produce has been carried off by man, or consumed by animals, the vegetable matter increases in such a proportion, that the soil approaches to a peat in its nature; and if in a situation where it can receive water from a higher district, it becomes spongy, and permeated with that fluid, and is gradually rendered incapable of supporting the nobler classes of vegetables.

Many peat-mosses seem to have been formed by the destruction of forests, in consequence of the imprudent use of the hatchet by the early cultivators of the country in which they exist; when the trees are felled in the out-skirts of a wood, those in the interior exposed to the influence of the winds, and having been accustomed to shelter, become unhealthy, and die in their new situation; and their leaves and branches gradually decomposing, produce a stratum of vegetable matter. In many of the great bogs in Ireland and Scotland, the larger trees that are found in the outskirts of them, bear the marks of having been felled. In the interior few entire trees are found; and the cause is, probably, that they fell by gradual

* For details on the subject of the weathering of rocks, and the manner in which soils are produced, the student is referred to Geological works. De la Beche's *Manual* and Lyell's *Principles*, may be particularized as containing much information that is applicable to Agriculture, although not always adduced with that view. Different rocks give rise to soils of very different characters, so much so indeed, that when soils have resulted from the decomposition of the rocks on which they rest, the transition from one group to another is often distinguishable at a glance, by the greater or lesser luxuriance of the vegetation. Hills of trap present quite a distinct character of vegetation from hills of sandstone, and soils derived from clay-slate, from soils derived from serpentine.

On slopes, in valleys, and on plains, the soil is generally not referable to any one group, but consists of layers of sand, clay, gravel, &c, derived from different, and often distant sources, by decomposing and transporting influences continued and varied through an immense lapse of time. Much information regarding soils will result from the increased attention now devoted by geologists to the upper layers or *drifts*, and the so-called diluvial layers. The efforts of geologists, whether they confirm, overturn, or modify the present fashionable glacier theory, cannot fail to throw light on a series of layers hitherto little examined, though in many localities more important to the agriculturist than all that lie below them.

decay; and that the fermentation and decomposition of the vegetable matter was most rapid where it was in the greatest quantity. *

Lakes and pools of water are sometimes filled up by the accumulation of the remains of aquatic plants; and in this case a sort of spurious peat is formed. The fermentation in these cases, however, seems to be of a

* In many points of view the nature of peat, and the history of its formation, are interesting subjects to the agriculturist. They afford the most satisfactory evidence of some important doctrines in vegetable physiology, and where peat abounds, it is of much practical importance to know how it can best be reclaimed and turned to account.

Peat consists of various vegetable substances in a peculiar state of decay. The peat of our heaths, mountains, and uplands, consists of the roots and stems of the common heaths, rushes, carices, mosses, lichens, liverworts, &c. The peat of our bogs occurs in much deeper layers, and consists of the remains of various plants. In the lower compact and compressed layers, it is often impossible to trace the individual plants that have contributed to its formation. At other times, and always in the upper layers, the plants are less broken down, and roots and stems of oak, pine, birch, hazel, alder, gale, and heath, can be readily detected, mixed with the remains of smaller plants. The interstices are filled chiefly with mosses, which continue growing at the top, while their lower portions have passed entirely into peat. The roots of oak are generally embedded in clay or loam, in which they had grown, and as the peat increased, oak seems to have been succeeded by alder and other trees that grow in boggy and marshy ground.

Peat has been produced from very different materials, and under circumstances in some respects different. Hence it has been divided into several varieties, as *marine*, *lacustrine*, *forest*, *marsh*, and *mountain*, or *moor* peat.

Various conditions are essential to the formation of peat. The bottom on which it is formed must be impervious to water, so as to cause stagnation. Many clays and clay marls are so; and these are the most common strata, on which it is found resting. Sometimes, indeed, a layer of fine white sand occurs immediately under the peat, but this in its turn will be found resting on impervious clay. In a district whose surface is much undulated, and where the upper layers consist of gravel, sand, and clay, peat will be found occupying some of the hollows, but not all, and it will be found that where the bottoms of the hollows consisted originally of clay, or where the rains could carry this substance down from their sides, and so render the bottom impervious, peat has been formed; and in the hollows whose bottoms and sides consisted of sand or gravel, no peat is met with. Clay, although the most common, is not the only substance that has rendered the bottom of peat-bogs impervious; decayed vegetable matter being found occasionally to produce the same effect.

Again, it appears to be essential to the formation of peat, that the mean temperature be low, and moisture abundant—conditions which the formation of peat would itself greatly favour, when once begun. This appears to be borne out by the fact, that peat only occurs in comparatively high latitudes. It is found in favourable situations all over the north of Europe, and an equivalent formation has been described as occurring in Tierra del Fuego and the Falkland Isles. The reason why it does not occur in lower latitudes and warmer climates is apparent. Where the heat is great, vegetable matter undergoes rapid decay, and the carbon of dead plants, whether derived from the carbonic acid of the air, the great reservoir of that gas, or from the decaying humus of the earth, is restored to the air. In cold climates, however, dead plants decay more slowly, and a great accumulation of partially decomposed organic matter takes place in the soil.

Liebig states that the greater part of peat consists of what is termed mould, a substance resulting from the complete decay of vegetable matter, and similar in composition to brown coal. The water that has stagnated in contact with peat is of a brown colour and contains in solution, according to the same autho-

different kind. Much more gaseous matter is evolved; and the neighbourhood of morasses in which aquatic vegetables decompose, is usually aguish and unhealthy; whilst that of the true peat, or peat formed on soils originally dry, is always salubrious.

The earthy matter of peats is uniformly analogous to that of the stratum on which they repose; the plants which have formed them must have derived the earths that they contained from this stratum. Thus in Wiltshire and Berkshire, where the stratum below the peat is chalk, calcareous earth abounds in the ashes, and very little alumina and silica. They likewise contain much oxide of iron and gypsum, both of which may be derived from the decomposition of the pyrites, so abundant in chalk.

Different specimens of peat that I have burnt, from the granitic and schistose soils of different parts of these islands, have always given ashes, principally siliceous and aluminous: and a specimen of peat from the county of Antrim, gave ashes which afforded very nearly the same constituents as the great basaltic stratum of the county.

Poor and hungry soils, such as are produced from the decomposition of granitic and sandstone rocks, remain very often for ages with only a thin

rity a substance resulting from the putrefaction of vegetable bodies. This substance possesses the power of absorbing oxygen from the air, and from every thing with which it comes in contact capable of readily affording it—hence the barrenness of peat, and hence also the bleached appearance of stones that have lain in peat bogs. When the solution has absorbed enough of oxygen it becomes clear, and a dark insoluble substance subsides, termed by chemists *coal of humus*.

On the removal of the stagnant water by draining, the air obtains admission into the soil, and such portions of vegetable matter as are still capable of decay absorb oxygen, and evolve carbonic acid, and the soil becomes greatly ameliorated. The addition of alkaline substances, such as quick-lime, greatly facilitates decomposition, and when the peat stratum is of considerable thickness, the most efficient method of reclaiming after draining, is pairing and burning, for the inorganic matters originally contained in the plants still remain, and the ashes act as a very powerful manure. The addition of clay, sand, or marl, is also of much importance, and can sometimes be most economically effected by stirring up and bringing to the surface small portions of the inorganic layer under the peat. But this requires to be done with care, sulphuret of iron being often found in it, and hence the red ochry deposit that for a long time appears in ditches cut for drying peat land. When the layer is too thick to admit of this, or when the subsoil even with exposure to air and frost, would take too long to become fit for mixing with the peat, inorganic matter is often dug, and in dry weather carted and spread in a thin dressing over the surface. When treated judiciously, reclaimed peat soils often prove very fertile, and possess the great advantage over reclaimed moor-land, that a greater proportion of organic matter in a useful form, can be retained in them, than it is easy to accumulate in the latter.

In consequence of the extensive drainage and general improvements of the last forty years, considerable check has been given to the formation of peat. At the present time, it is believed to be on the increase, only in a few localities where wood has been entirely neglected, and on the sites of some of the highland forests. On some elevated mountains, it is also, no doubt, on the increase, but there its growth is extremely slow. On elevated moors in many places peat might be reclaimed to useful pasture for sheep by irrigation, but unfortunately in Scotland this mode of improvement has been hitherto almost totally neglected.

Many interesting particulars regarding peat, are to be found in RENNIE's *Essays*, and in the papers of M'CULLOCH and others. To the geologist the study of peat is important not merely on its on account, but as affording data on which one of the theories of the formation of coal has, to a certain extent, been founded.

covering of vegetation. Soils, from the decomposition of limestone, chalks, and basalts, are often clothed by nature with the perennial grasses; and afford, when ploughed up, a rich bed of vegetation for every species of cultivated plant.

Rocks and strata from which soils have been derived, and those which compose the more interior solid parts of the globe, are arranged in a certain order: and as it often happens that strata very different in their nature are associated together, and that the strata immediately beneath the soil contain materials which may be of use for improving it, a general view of the nature and position of rocks and strata in nature, will not, I trust, be unacceptable to the scientific farmer *

Rocks are generally divided by geologists into two grand divisions, distinguished by the names of *primary* and *secondary*.†

The primary rocks are composed of pure crystalline matter, and contain no fragments of other rocks.

The secondary rocks or strata, consist only partly of crystalline matter; contain fragments of other rocks or strata; often abound in the remains of vegetables and marine animals: and sometimes contain the remains of land animals.

The primary rocks are generally arranged in large masses, or in layers vertical, or more or less inclined to the horizon.

The secondary rocks are usually disposed in strata or layers, parallel, or nearly parallel to the horizon.

The number of primary rocks which are commonly observed in nature, are eight.

First, *granite*, which, as has been mentioned, is composed of quartz, felspar, and mica; when these bodies are arranged in regular layers in the rock, it is called *gneiss*.

Second, *micaceous schistus*, which is composed of quartz and mica arranged in layers, which are usually curvilineal.

Third, *sienite*, which consists of the substance called hornblende and felspar.

Fourth, *serpentine*, which is constituted by felspar and a body named resplendent hornblende; and their separate crystals are often so small as to give the stone a uniform appearance: this rock abounds in veins of a substance called *steatite*, or *soap rock*.

* Since the date at which the digest in the text appeared, geology has become in a great measure a new science. Instead of attempting to give an abstract, which from its brevity behoved to be unsatisfactory, it is better simply to refer the student to the recent elementary works on the subject, such as De la Beche's *Manual*, De la Beche's *How to Observe*, Lyell's *Principles*, Lyell's *Elements*, also to Greenough's *Geological Map of England*, M'Culloch's *Geological Map of Scotland*, together with numerous Memoirs and Maps referring to areas of smaller extent.

Of the application of geology to agriculture, an excellent sketch has been given by Professor Johnston in his Lectures, in course of publication, but the subject is so extensive and important, and so many of the details have yet to be worked out, that it demands a separate treatise, which, it is to be hoped, some of the distinguished geologists of the day will soon supply.

† To which would now be added *tertiary* and *post-tertiary*, but a more common as well as less theoretical division is into stratified and unstratified. The latter contains granite, trap, porphyry, &c. The stratified rocks are divided into fossiliferous and non-fossiliferous, and of these the former is divided into various groups, distinguished by lithological characters, organic contents, and position.

Fifth, *porphyry*, which consists of crystals of felspar, embedded in the same material, but usually of a different colour.

Sixth, *granular marble*, which consists entirely of crystals of carbonate of lime; and which, when its colour is white, and texture fine, is the substance used by statuaries.

Seventh, *chlorite schist*, which consists of chlorite, a green or gray substance, somewhat analogous to mica and felspar.

Eighth, *quartzose rock*, which is composed of quartz in a granular form, sometimes united to small quantities of the crystalline elements, which have been mentioned as belonging to the other rocks.

The secondary rocks are more numerous than the primary: but twelve varieties include all that are usually found in these islands.

First, *grauwacke*, which consists of fragments of quartz, or chlorite schist, embedded in a cement, principally composed of felspar.

Second, *siliceous sandstone*, which is composed of fine quartz or sand, united by a siliceous cement.

Third, *limestone*, consisting of carbonate of lime, more compact in its texture than the granular marble; and often abounding in marine exuvia.

Fourth, *aluminous schist*, or *shale*, consisting of the decomposed materials of different rocks cemented by a small quantity of ferruginous or siliceous matter; and often containing the impressions of vegetables.

Fifth, *calcareous sandstone*, which is calcareous sand, cemented by calcareous matter.

Sixth, *ironstone*, formed of nearly the same materials as aluminous schist, or shale; but containing a much larger quantity of oxide of iron.

Seventh, *basalt* or *whinstone*, which consists of felspar and hornblende, with materials derived from the decomposition of the primary rocks; the crystals are generally so small as to give the rock a homogeneous appearance; and it is often disposed in very regular columns, having usually five or six sides.

Eighth, *bituminous* or *common coal.*

Ninth, *gypsum*, the substance so well known by that name, which consists of sulphate of lime; and often contains sand.

Tenth, *rock salt.*

Eleventh, *chalk*, which usually abounds in remains of marine animals, and contains horizontal layers of flints.

Twelfth, *plum-pudding stone*, consisting of pebbles cemented by a ferruginous or siliceous cement.

To describe more particularly the constituent parts of the different rocks and strata will be unnecessary; at any time, indeed, details on this subject are useless, unless the specimens are examined by the eye; and a close inspection and comparison of the different species, will, in a short time, enable the most common observer to distinguish them.

The highest mountains in these islands, and indeed in the whole of the old continent, are constituted by granite; and this rock has likewise been found at the greatest depths to which the industry of man has as yet been able to penetrate; micaceous schist is often found immediately upon granite; serpentine or marble upon micaceous schist: but the order in which the primary rocks are grouped together is various. Marble and serpentine are usually found uppermost; but granite, though it seems to form the foundation of the rocky strata of the globe, is yet sometimes discovered above micaceous schist.

The secondary rocks are always incumbent on the primary; the lowest of them is usually grauwacke: upon this, limestone or sandstone is often

found; coal generally occurs between sandstone or shale; basalt often exists above sandstone and limestone; rock salt almost always occurs associated with red sandstone and gypsum. Coal, basalt, sandstone, and limestone, are often arranged in different alternate layers, of no considerable thickness, so as to form a great extent of country. In a depth of less than 500 yards, 80 of these different alternate strata have been counted.

The veins which afford metallic substances, are fissures more or less vertical, filled with a material different from the rock in which they exist.

This material is almost always crystalline; and usually consists of calcareous spar, fluor spar, quartz, or heavy spar, either separate or together. The metallic substances are generally dispersed through, or confusedly mixed with these crystalline bodies. The veins in hard granite seldom afford much useful metal; but in the veins in soft granite and in gneiss, tin, copper, and lead are found. Copper and iron are the only metals usually found in the veins in serpentine. Micaceous schist, syenite, and granular marble, are seldom metalliferous rocks. Lead, tin, copper, iron, and many other metals, are found in the veins in chlorite schist. Grauwacke, when it contains few fragments, and exists in large masses, is often a metalliferous rock. The precious metals, likewise iron, lead, and antimony, are found in it; and sometimes it contains veins or masses of *stone-coal*, or coal free from bitumen. Limestone is the great metalliferous rock of the secondary family; and lead and copper are the metals most usually found in it. No metallic veins have ever been found in shale, chalk, or calcareous sandstone; and they are very rare in basalt and siliceous sandstone.

In cases where veins in rocks are exposed to the atmosphere, indications of the metals they contain may be often gained from their superficial appearance. Whenever fluor spar is found in a vein, there is always strong reason to suspect that it is associated with metallic substances. A brown powder at the surface of a vein always indicates iron, and often tin; a pale yellow powder, lead; and a green colour in a vein denotes the presence of copper.

It may not be improper to give a general description of the geological constitution of Great Britain and Ireland. Granite forms the great ridge of hills extending from Land's end through Dartmoor into Devonshire. The highest rocky strata in Somersetshire are grauwacke and limestone. The Malvern hills are composed of granite, syenite, and porphyry. The highest mountains in Wales are chlorite-schist, or grauwacke. Granite occurs at mount Sorrel in Leicestershire. The great range of the mountains in Cumberland and Westmoreland, are porphyry, chlorite, schist, and grauwacke; but granite is found at their western boundary. Throughout Scotland the most elevated rocks are granite, syenite, and micaceous schistus. No true secondary formations are found in South Britain, west of Dartmoor; and no basalt south of the Severn. The chalk district extends from the western part of Dorsetshire, to the eastern coast of Norfolk. The coal formations abound in the district between Glamorganshire and Derbyshire; and likewise in the secondary strata of Yorkshire, Durham, Westmoreland, and Northumberland. Serpentine is found near Cape Lizard in Cornwall, at Portsoy in Banffshire, and in Ayrshire. Black and grey granular marble is found near Padstow in Cornwall; and other coloured primary marbles exist in the neighbourhood of Plymouth. Coloured primary marbles are abundant in Scotland; and white granular marble is found in the Isle of Skye, in Assynt, and on the banks of Loch Shin in Sutherland: the principal coal formations in Scotland are in

Dumbartonshire, Ayrshire, Fifeshire, and on the banks of the Brora in Sutherland. Secondary limestone and sandstone are found in most of the low countries north of the Mendip hills.

In Ireland there are five great associations of primary mountains; the mountains of Morne in the county of Down; the mountains of Donegal; those of Mayo and Galway, those of Wicklow, and those of Kerry. The rocks composing the first four of these mountain chains are principally granite, gneiss, syenite, micaceous schist, and porphyry. The mountains of Kerry are chiefly constituted by granular quartz, and chlorite-schist. Coloured marble is found near Killarney; and white marble on the western coast of Donegal.

Limestone and sandstone are the common secondary rocks found south of Dublin. In Sligo, Roscommon, and Leitrim, limestone, sandstone, shale, iron stone, and bituminous coal are found. The secondary hills in these counties are of considerable elevation; and many of them have basaltic summits. The northern coast of Ireland is principally basalt; this rock commonly reposes upon a white limestone containing layers of flint, and the same fossils as chalk; but it is considerably harder than that rock. There are some instances, in this district, in which columnar basalt is found above sandstone and shale, alternating with coal. The stone-coal of Ireland is principally found in Kilkenny, associated with limestone and grauwacke. *

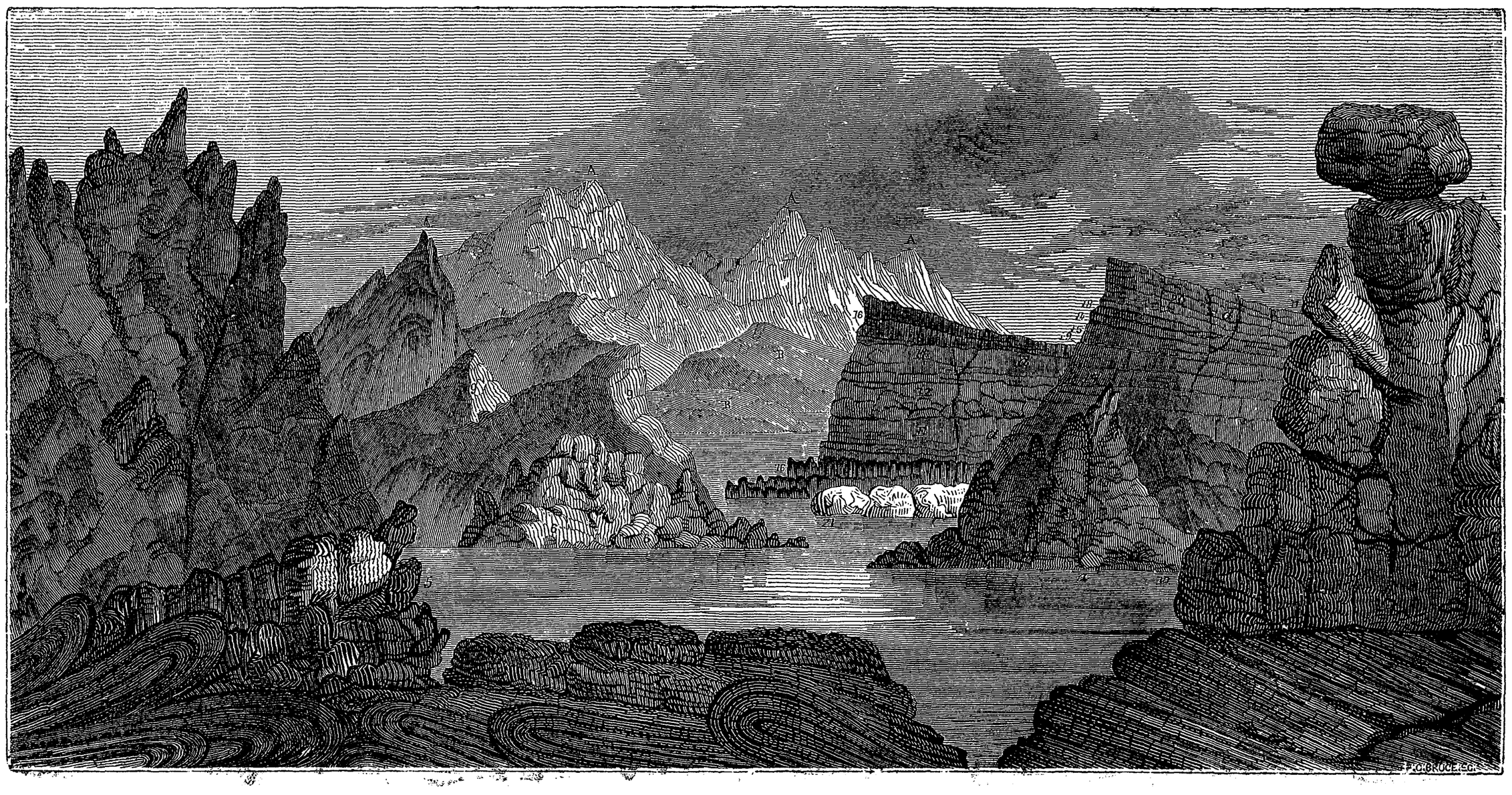
It is evident from what has been said concerning the production of soils from rocks, that there must be at least as many varieties of soils as there are species of rocks exposed at the surface of the earth; in fact, there are many more. Independent of the changes produced by cultivation and the exertions of human labour, the materials of strata have been mixed together, and transported from place to place by various great alterations that have taken place in the system of our globe, and by the constant operation of water.

To attempt to class soils with scientific accuracy, would be a vain labour; the distinctions adopted by farmers are sufficient for the purposes of agriculture; particularly if some degree of precision be adopted in the application of terms. The term sandy, for instance, should never be applied to any soil that does not contain at least $\frac{7}{8}$ of sand; sandy soils that effervesce with acids should be distinguished by the name of calcareous sandy soils, to distinguish them from those that are siliceous. The term clayey soil should not be applied to any land which contains less than one-sixth of impalpable earthy matter, not considerably effervescing

* Fig 25 will give a general idea of the appearance and arrangement of rocks and veins:—

1. Granite.
2. Gneiss.
3. Micaceous Schistus.
4. Syenite.
5. Serpentine.
6 Porphyry.
7. Granular Marble.
8. Chlorite Schist.
9. Quartzose Rock.
10. Grauwacke.
11. Siliceous Sandstone.
12. Limestone.
13. Shale.
14. Calcareous Sandstone.
15. Iron Stone.
16. Basalt.
17. Coal.
18. Gypsum.
19. Rocksalt.
20. Chalk.
21. Plum-pudding Stone.

AA. Primary Mountains.
BB. Secondary Mountains.
aa. Veins.—D.



with acids. The word loam should be limited to soils, containing at least one-third of impalpable earthy matter, copiously effervescing with acids. A soil to be considered as peaty, ought to contain at least one-half of vegetable matter.*

In cases where the earthy part of a soil evidently consists of the decomposed matter of one particular rock, a name derived from the rock may with propriety be applied to it. Thus, if a fine red earth be found immediately above decomposing basalt, it may be denominated basaltic soil. If fragments of quartz and mica be found abundant in the materials of the soil, which is often the case, it may be denominated granitic soil; and the same principles may be applied to other like instances.

In general, the soils, the materials of which are the most various and heterogeneous, are those called alluvial, or which have been formed from the depositions of rivers; many of them are extremely fertile. I have examined some productive alluvial soils, which have been very different in their composition. The soil, which has been mentioned page 112, as very productive, from the banks of the river Parret in Somersetshire, afforded me eight parts of finely divided earthy matter, and one part of siliceous sand; and an analysis of the finely divided matter gave the following results:—

360 parts of Carbonate of lime.
25 .. . Alumina.
20 . . Silica.
8 .. . Oxide of iron.
19 .. .. Vegetable, animal, and saline matter.

A rich soil, from the neighbourhood of the Avon, in the valley of Evesham, in Worcestershire, afforded me three-fifths of fine sand, and two-fifths of impalpable matter; the impalpable matter consisted of

35 Alumina.
41 Silica.
14 Carbonate of lime.

* The want of a good classification and nomenclature of soils has been much felt, since greater attention came to be given to agricultural subjects. Until some uniform system of naming soils is generally adopted, it is impossible to reap half the benefit that would arise from the reports of experiments on manures, and other similar subjects, with which the agricultural periodicals of the day abound.

It is, perhaps, impossible to classify and name soils in the best manner, till accurate analyses, both chemical and mechanical, have been made, but since clay, sand, lime, and humus, constitute the principal part of all soils, they may be classified in a manner sufficiently accurate for ordinary purposes, by ascertaining the relative proportions of these constituents.

Dr. Daubeny, in his excellent lecture on the application of science to agriculture, (*Journal of the Royal Agricultural Society of England,*) has proposed the general adoption of Schubler's classification and nomenclature, (see appendix to the present lecture) and as it requires but little skill in manipulation to refer a soil to its true place in the table, it cannot be too generally known to those who report experiments on the fertilizing power of certain manures. Schubler's classification can be regarded only as a provisional one, seeing it is based on a very general examination of soils, and takes no notice of constituents, such as phosphoric acid and alkalies, whose determination would infer an accurate analysis; and it may be added, that no classification that omits among the characters of soils, a statement of the *gradations* of sand and gravel contained, can be considered as complete.

3 Oxide of iron.
7 Vegetable, animal, and saline matter.

A specimen of good soil from Tiviot-dale, afforded five-sixths of fine siliceous sand, and one-sixth of impalpable matter; which consisted of

41 Alumina.
42 Silica.
4 Carbonate of lime.
5 Oxide of iron.
8 Vegetable, animal, and saline matter.

A soil yielding excellent pasture from the valley of the Avon, near Salisbury, afforded one eleventh of coarse siliceous sand; and the finely divided matter consisted of

7 Alumina.
14 Silica,
63 Carbonate of lime.
2 Oxide of iron.
14 Vegetable, animal, and saline matter.

In all these instances the fertility seems to depend upon the state of division, and mixture of the earthy materials, and the vegetable and animal matter; and may be easily explained on the principles which I have endeavoured to elucidate in the preceding part of this Lecture.

In ascertaining the composition of sterile soils. with a view to their improvement, any particular ingredient which is the cause of their unproductiveness, should be particularly attended to; if possible, they should be compared with fertile soils in the same neighbourhood, and in similar situations, as the difference of the composition may, in many cases, indicate the most proper methods of improvement. If on washing a sterile soil it is found to contain the salts of iron, or any acid matter, it may be ameliorated by the application of quick lime. A soil of good apparent texture from Lincolnshire, was put into my hands by Sir Joseph Banks as remarkable for sterility: on examining it, I found that it contained sulphate of iron; and I offered the obvious remedy of top dressing with lime, which converts the sulphate into a manure. If there be an excess of calcareous matter in the soil, it may be improved by the application of sand, or clay, Soils too abundant in sand are benefitted by the use of clay, or marl, or vegetable matter. A field belonging to Sir Robert Vaughan at Nannau, Merionethshire, the soil of which was a light sand, was much burnt up in the summer of 1805; I recommended to that gentleman the application of peat as a top dressing, The experiment was attended with immediate good effects; and Sir Robert last year informed me, that the benefit was permanent. A deficiency of vegetable or animal matter must be supplied by manure. An excess of vegetable matter is to be removed by burning, or to be remedied by the application of earthy materials. The improvement of peats, or bogs, or marsh lands, must be preceded by draining; stagnant water being injurious to all the nutritive classes of plants. Soft black peats, when drained, are often made productive by the mere application of sand or clay as a top dressing. When peats are acid, or contain ferruginous salts, calcareous matter is absolutely necessary in bringing them into cultivation. When they abound in the branches and roots of trees, or when their surface entirely consists of living vegetables, the wood or the vegetables must either be carried off, or be destroyed by burning. In the last case their ashes afford earthy ingredients, fitted to improve the texture of the peat.

The best natural soils are those of which the materials have been de-

rived from different strata; which have been minutely divided by air and water, and are intimately blended together: and in improving soils artificially, the farmer cannot do better than imitate the processes of nature.

The materials necessary for the purpose are seldom far distant: coarse sand is often found immediately on chalk; and beds of sand and gravel are common below clay. The labour of improving the texture or constitution of the soil, is repaid by a great permanent advantage; less manure is required, and its fertility insured: and capital laid out in this way secures for ever, the productiveness, and consequently the value of the land. *

* It is much to be regretted that these valuable suggestions have been acted on to so small an extent. In all parts of the country fields may be seen in which manure lies locked up, or is unduly wasted, in consequence of the want of proper texture in the soils. This might be permanently remedied by the application of mineral matter. The expense of this plan, coupled with an inadequate perception of the benefit that would be derived, forms the usual bar to its adoption. Of late years, deep ploughing, andgreater attention to the mineral portion of composts, have done something to improve matters; but it sometimes happens, that the subsoil is not of a nature to improve the soil when mixed with it, and the same objection, applies in some instances, to the road-scrapings and ditch-scourings, used in compost. When these substances are suitable, the farmer must be very ignorant who does not use them largely, and when they are not suitable to his particular soil, he ought to examine every road-cutting and stream-channel in his vicinity, and he will rarely fail to discover something that will suit his purpose.

SCHUBLER'S CLASSIFICATION AND NOMENCLATURE OF SOILS, AS RECOMMENDED BY DR DAUBENY.

(From the Journal of the Royal Agricultural Society of England, Vol. III. p. 156.)

Names of the Different Descriptions of Soil.			Proportions of Ingredients in every 100 Parts.				Agricultural Designations and general Relations with Reference to their Produce.*
Classes.	Orders.	Species.	Clay.	Lime.	Humus.	Sand.	
1. Argillaceous Soils. — Above 50 per cent. of Clay. Not more than 5 per cent. of Lime.	Without Lime.	Poor	Above 50	0	0· to 0·5	The Remainder.	*Land for Wheat and Spelt.* The calcareous kinds not too rich in clay, and not too poor in sand and humus, give good returns. Wheat, spelt, barley, rape, beans, flax, and clover flourish in it especially. Those poor in humus are still suited for oats.
		Intermediate	" 50	0	0·5 to 1·5		
		Rich	" 50	0	1·5 to 5·0		
	With Lime.	Poor	Above 50	0·5 to 5·0	0· to 0·5	..	
		Intermediate	" 50	0·5 to 5·0	0·5 to 1·5	..	
		Rich	" 50	0·5 to 5·0	1·5 to 5·0	..	
2. Loamy Soils. — Not more than 50 nor less than 30 per cent. of Clay. Not more than 5 of Lime.	Without Lime.	Poor	30 to 50	0	0· to 0·5	..	*Land for Barley.* The soils which are rich in humus, and contain lime, are well suited even for wheat and spelt, and often approach nearly to the foregoing kinds. They are, moreover, suited for Triticum dicoccum? (Emmer), one-grained wheat (Einkorn), rye, oats, rape, (Reps,) flax, and clover.
		Intermediate	30 to 50	0	0·5 to 1·5	..	
		Rich	30 to 50	0	1·5 to 5·0	..	
	With Lime.	Poor	30 to 50	0·5 to 5·0	0· to 0·5	..	
		Intermediate	30 to 50	0·5 to 5·0	0·5 to 1·5	..	
		Rich	30 to 50	0·5 to 5·0	1·5 to 5·0	..	
3. Sandy Loams. — Not more than 30 nor less than 20 per cent. of Clay. Not more than 5 of Lime.	Without Lime.	Poor	20 to 30	0	0· to 0·5	..	*Land for Barley and Oats.* Less suited for wheat and spelt than the former soils, but even better adapted for Triticum dicoccum and T. monococcum, as well as for rye. Potatoes, turnips, and other roots thrive well in it.
		Intermediate	20 to 30	0	0·5 to 1·5	..	
		Rich	20 to 30	0	1·5 to 5·0	..	
	With Lime.	Poor	20 to 30	0·5 to 5·0	0· to 0·5	..	
		Intermediate	20 to 30	0·5 to 5·0	0·5 to 1·5	..	
		Rich	20 to 30	0·5 to 5·0	1·5 to 5·0	..	
4. Loamy Sands. — Not more than 20 nor less than 10 per cent. of Clay. Less than 5 per cent. of Lime.	Without Lime.	Poor	10 to 20	0	0· to 0·5	..	*Land for Oats and Rye.* Barley thrives well in those rich in humus. They are also well suited for buckwheat. Wheat, spelt, and clover do not succeed.
		Intermediate	10 to 20	0	0·5 to 1·5	..	
		Rich	10 to 20	0	1·5 to 5·0	..	
	With Lime.	Poor	10 to 20	0·5 to 5·0	0· to 0·5	..	
		Intermediate	10 to 20	0·5 to 5·0	0·5 to 1·5	..	
		Rich	10 to 20	0·5 to 5·0	1·5 to 5·0	..	

* This of course chiefly applies to the soil and climate of Germany.

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Classes.	Orders.	Species.	Clay.	Lime.	Humus.	Sand.	
5. Sandy Soils. — Not more than 10 per cent. of Clay. Less than 5 per cent. of Lime.	Without Lime.	Poor	0· to 10	0	0· to 0·5	The Remainder.	*Land for Rye.* Of less value; often cultivated only every third year, and the poor land often not at all. Those containing humus are chiefly fit for buckwheat, oats, hemp, tobacco, potatoes, and spergula arvensis.
		Intermediate	0· to 10	0	0·5 to 1·5	..	
		Rich	0· to 10	0	1·5 to 5·0	..	
	With Lime.	Poor	0· to 10	0·5 to 5·0	0· to 0·5	..	
		Intermediate	0· to 10	0·5 to 5·0	0·5 to 1·5	..	
		Rich	0· to 10	0·5 to 5·0	1·5 to 5·0	..	
6. Marly Soils. — More than 5, not more than 20 per cent. of Lime.	Argillaceous.	Poor	Above 50	5 to 20	0· to 0·5	..	Chiefly suited for wheat and spelt, together with lucern and sainfoin.
		Intermediate	" 50	5 to 20	0·5 to 1·5	..	
		Rich	" 50	5 to 20	1·5 to 5·0	..	
	Loamy.	Poor	30 to 50	5 to 20	0· to 0·5	..	Less suited for wheat and spelt, more so for barley, Triticum dicoccum and T. monococcum, but are amongst the most fertile soils.
		Intermediate	30 to 50	5 to 20	0·5 to 1·5	..	
		Rich	30 to 50	5 to 20	1·5 to 5·0	..	
	Belonging to the Sandy Loams.	Poor	20 to 30	5 to 20	0· to 0·5	..	Barley and Oats.
		Intermediate	20 to 30	5 to 20	0·5 to 1·5	..	
		Rich	20 to 30	5 to 20	1·5 to 5·0	..	
	Belonging to the Loamy Sands.	Poor	10 to 20	5 to 20	0· to 0·5	..	Oats and Rye.
		Intermediate	10 to 20	5 to 20	0·5 to 1·5	..	
		Rich	10 to 20	5 to 20	1·5 to 5·0	..	
	Humous.	Clayey	Above 50	5 to 20	Above 5·0	..	The humous, and argillaceous, marly soils are amongst the best that exist.
		Loamy	30 to 50	5 to 20	" 5·0	..	
		Sandy	20 to 30	5 to 20	" 5 0	..	
	Argillaceous.	Poor	Above 50	Above 20	0· to 0·5	..	
		Intermediate	" 50	" 20	0·5 to 1·5	..	
		Rich	" 50	" 20	1·5 to 5·0	..	
	Loamy.	Poor	30 to 50	" 2	0· to 0.5	..	
		Intermediate	30 to 50	" 20	0·5 to 1·5	..	
		Rich	30 to 50	" 20	1·5 to 5·0	..	

Names of the Different Descriptions of Soil.			Proportions of Ingredients in every 100 Parts.				Agricultural Designations and general Relations with reference to their produce.
Classes.	Orders.	Species.	Clay.	Lime.	Humus	Sand.	
7. Calcareous Soils. — Containing more than 20 per cent of Lime.	Belonging to the Sandy Loams.	Poor	20 to 30	Above 20	0· to 0·5	The Remainder.	The argillaceous soils often approach in value to the argillaceous marls; the remaining orders of both these classes equally correspond one with the other· to the most valuable belongs, as in the former case, the humous. Those wanting in humus require much manure. Those rich in clay are well suited for spelt and wheat, oats, Triticum dicoccum, lucern, and sainfoin thrive in them. Their value is much decreased by containing an excess of lime.
		Intermediate	20 to 30	" 20	0·5 to 1·5		
		Rich	20 to 30	" 20	1·5 to 5·0		
	Belonging to the Loamy Sands.	Poor	10 to 20	" 20	0· to 0·5		
		Intermediate	10 to 20	" 20	0·5 to 1·5		
		Rich	10 to 20	" 20	1·5 to 5·0		
	Sandy.	Poor	0 to 10	" 20	0· to 0·5	Any portion less than 80 per cent.	
		Intermediate	0 to 10	" 20	0·5 to 1·5		
		Rich	0 to 10	" 20	1·5 to 5.0		
	Pure.	Poor	0	" 99	0· to 0·5	None.	
		Intermediate	0	" 98	0·5 to 1·5	None.	
		Rich	0	" 94	1·5 to 5·0	None.	
	Humous.	Clayey	Above 50	" 20	Above 5·0	The Remainder.	
		Loamy	30 to 50	" 20	" 5·0		
		Sandy	20 to 30	" 20	" 5·0		
8. Humous Soils. — Containing more than 5 per cent. of Humus.	Soluble mild Humus.	Clayey	Above 50	With or without Lime.	Above 5·0		The value of these soils is greatly augmented by admixture with lime. Those which contain lime and clay are suited for wheat, spelt, barley, and oleaginous plants, the loamy and sandy are especially adapted for oats, and in most places for wheat. The peaty and acid humous may be made fruitful by admixture with lime, sand, and clay.
		Loamy	30 to 50		" 5·0		
		Sandy	20 to 30		" 5·0		
	Insoluble carbonized or acid Humus.	Clayey	Above 50	With or without Lime.	" 5 0		
		Loamy	30 to 50		" 5·0		
		Sandy	20 to 30		" 5·0		
	Insoluble fibrous Vegetable Matter.	Bog and Peat Earth	With Lime.		" 5·0		
			Without Lime.		" 5·0		

For the sake of those unaccustomed even to very simple chemical operations, it may not be out of place to show, how an unknown soil may be referred to its proper place in the foregoing table.

Preliminary Process.—The classification is applicable only to soils in a dried state, that is to say, to soils that have been exposed to such a temperature as will drive off nearly all the water they contain, without decomposing the humus or other organic matters. Hence, when a specimen of an unknown soil is to be examined, a preliminary process is to dry it. The soil, as taken from the field, is first freely exposed to the air, till it becomes dry at ordinary temperatures. Any convenient quantity—100 grains perhaps—is weighed out; and, in doing this, care must be taken to select a fair sample, not rejecting any small stones that may be in it. This weighed quantity of air-dried earth is introduced into a short test tube, and heated in a saline or oil bath at 300° F., till it ceases to lose weight. The loss of weight is then carefully ascertained. This, although not involved in the classification, is, in itself, an interesting point, and the percentage of water being known, a portion of air-dried soil, corresponding to 100 or 1000 parts of thorough dried soil, can be used in any subsequent operation.

Process 1 —The thorough dried sample, or a determinate portion of it, is transferred to a platinum crucible, and ignited over a spirit lamp or gas furnace; the loss of weight is determined, and reckoned as humus or organic matter.

Process 2.—What remains after ignition is transferred to a test glass, and mixed with ten fluid ounces of distilled or rain water, after which, half a fluid ounce of muriatic acid is added, and the whole is stirred together, and allowed to stand for an hour or two. The contents of the test glass are next brought on a weighed filter, and when the liquid portion has passed through, the filter is several times washed with pure water; the filter and its contents are dried at 300° F , and weighed. The loss of weight is reckoned lime.

Process 3 —The contents of the filter-paper are carefully brushed off into a tall narrow test glass, and mixed with a convenient quantity of water—say four ounces; the whole is well stirred till the soil is completely mixed and diffused through the water, after which it is allowed to settle, till the sand and coarser parts have completely subsided, which will generally take place in a minute or a minute and a half. The portion still held in suspension is poured off into another vessel, to be afterwards filtered. A second portion of water is poured on the part that subsided, the whole is well stirred up, and the coarser parts again allowed to settle, while the suspended portion is poured off for filtration; and this process is continued till only sand and matters incapable of remaining suspended in water for a short time, remain The suspended matter having been collected on a weighed filter, dried at 300° F , and weighed, is regarded as clay.

For the purpose of saving time, a portion of air-dried soil, corresponding to 200 or 300 grains of thorough dried soil, may be employed, but as a general rule, it is better to employ the residuum of process 2d, for ascertaining the proportion of clay.

Supposing that in examining an unknown soil, we obtain in process 1st four per cent , in process 2d sixteen per cent , and in process 3d thirty-eight per cent , the soil would rank as a *rich loamy marl*, according to Schübler's classification.

By the process above detailed, any soil of the first 7 classes may be referred to its proper place in the table, and the mode of procedure with humous soils may be inferred from what is stated further on in this appendix.

ANALYSIS OF SOILS.

Preliminary Remarks.—It was intimated in a note, page 98, that from the number of deviations it was thought necessary to make from the process in the text, the details of these alterations, would be given in this place.

In the following directions it is assumed that the student is acquainted with the general doctrines of chemistry; and although mention is generally made of the kind of apparatus employed, and wood cuts occasionally introduced, it is necessary to remark, that no written directions, however full, can make up for the want of regular instructions, and practice under an experienced chemist. The student who has not enjoyed these advantages, will have to encounter many difficulties, which will render his first attempts of little value, beyond impressing on him the absolute necessity of caution, patience, accuracy, and conscientiousness, and of rendering him more capable of reading with profit, books on Chemical Analysis.

Separate lists of the different pieces of apparatus most useful, will afterwards be given. The student may experience some difficulty in obtaining *pure* reagents. Some of these may be procured from dealers in chemicals, and others may require to be prepared. In either case, it will save much time and trouble, to ascertain, before using them in any exact analysis, that they are *really* pure.

When a specimen of soil is to be analysed, it is collected, as described in the text, page 96, and exposed to the air till it is as dry as it will become at ordinary temperatures. In this state it is spoken of as air-dried soil: it should be kept in wide-mouthed bottles well corked. It still, however, contains water, of which it can be deprived only by heat; yet this heat must be regulated so as not to rise so high as would decompose the organic matters present.

Determination of Water in Soils.—This is done as already described, page 131, in the directions for determining the species of any unknown soil, according to Schübler's classification. It is true that by this method all the water is not driven off, particularly if the soil contains much clay, and hence one of the principal sources of loss in analysis, but it must be submitted to, as the degree of heat necessary to drive off the last traces of water would decompose the organic constituents. The percentage of water having been determined, it saves calculation, when in the subsequent parts of the analysis, portions of air-dried soil are taken, corresponding to round numbers, such as 50, 100, 200, &c., parts of thorough dried soil.

Mechanical Analysis.—Agriculturists are indebted to the Rev. Mr Rham for calling attention to the great importance of ascertaining the *texture of soils*, or the relative proportions of small stones, sand, and clay contained in them. On comparing together the analyses of two very different soils, it not unfrequently happens, that the resemblance is so great in the quantities of silica, alumina, lime, and humus, and indeed in all the constituents, that one would be led to conclude, that in the same climate, the two soils would be equally fertile, and suited to the same kind of crops; whereas, had the proportions of grit, sand, and clay, been stated, it would have appeared that the one behoved to have a much closer texture than the other, and consequently to be of different value, to have a different relation to air and moisture, and to require a different course of cultivation. Schübler's

classification, already given, would be rendered much more useful were account taken of the degrees of division of the portion in it reckoned as sand.

The following processes of mechanical examination differ from those of Mr Rham, chiefly, in beginning with the separation of the impalpable portion, and after that, graduating the coarser parts—an order of procedure susceptible of greater accuracy.

Separation and Estimation of Impalpable Matter.—A portion of air-dried soil, corresponding to 400 or 500 grains of thorough-dried soil, is weighed, and mixed with water in a Phillips's precipitate glass, Fig. 26. The mixture is stirred from time to time, till the soil is thoroughly mixed and diffused through the water. The precipitate glass is then filled up with more water, and the mixture is well stirred up. It is then allowed to stand *one* minute, and a syphon, Fig. 27, is introduced. The syphon most useful for this purpose is that of Mitscherlich, which has the shorter leg slightly bent upwards, to prevent its sucking up any portion of the coarser matter that has subsided to the bottom. It is filled by closing the aperture *g*, by the forefinger, and sucking out the air at *o*, till the water entering by *c* rises into the bulb. On removing the forefinger the water flows. It is allowed to do so till all the water, with the finely divided matter held in suspension, is drawn off down to the point at which there is danger of disturbing the sediment, or till the air enters by the aperture *c*. The precipitate glass is again filled up with water, and after standing for some time, and being frequently well stirred up, the rough portion is allowed *one* minute to subside, and the water and suspended matter run off as before; and this process is repeated, till no matter capable of remaining suspended for more than one minute is left.

Fig. 26.

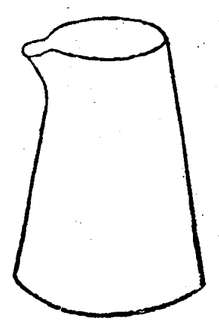
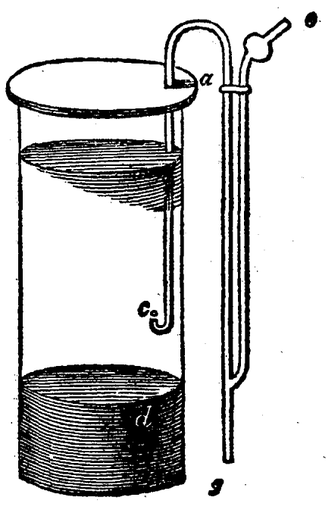
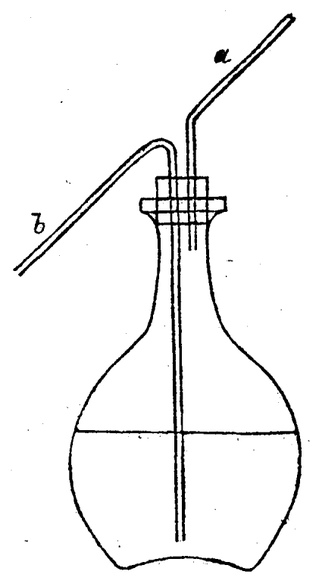


Fig. 27.



The water and suspended matter may be at once run into a large weighed filter, but in general it will be found more convenient to run the whole into a large jar or precipitate glass, to be afterwards filtered, dried, and estimated. If the soil contains much fine clay, the impalpable matter may take several days to settle to the bottom completely. It should be allowed to do so. The clear water may then be cautiously poured off, or what is better, run off by the syphon. The impalpable matter is then well stirred up with the small portion of water left by the syphon above it, and brought on a weighed filter. From this filter the water may not at first run quite pure, and if so, the muddy water is returned to the filter, after being used to wash out the last portions of impalpable matter from the glass. By the time the whole is got on the filter, the pores of the paper becoming partially filled up with clay, the water will pass through quite pure. When this is the case the impalpable matter is washed with distilled water by means of the washing bottle, Fig. 28. The filter with its contents is then set in a warm place to dry, after which it is dried in the bath at 300° till it ceases to lose weight. The weight

Fig. 28.



of the dry filter paper, which had been previously ascertained, is now deducted, and the exact weight of the impalpable matter noted.

The clear solution separated from the impalpable matter contains the soluble portions of the soil, but unless means have been taken to ascertain that it contains all that is soluble, it cannot be used for ascertaining the quantity of these substances, although, after concentration, it may very properly be used for a qualitative examination.

Estimation of the Small Stones, Grit, and Sand.—The coarser part left in the precipitate glass, out of which the suspended portion was originally run, is now washed out of it, and brought on a weighed filter. When the water has passed through, it is washed with a little distilled water, dried at 300° and weighed; and the weight of the filter paper being deducted, the remainder is the gross weight of the coarser parts.

The coarser parts being now free from very finely divided matter, and quite dry, can be easily sifted without sensible loss, and by using sieves of different degrees of fineness, may be separated into as many gradations as the operator thinks necessary. I have used sieves of all degrees of fineness, and find that for all practical purposes *three* are quite sufficient. The first is of wire gauze, 10 threads to the inch; the second also of wire gauze, 40 threads to the inch, and the third is of very uniform muslin, 100 threads to the inch. If wire gauze of this degree of fineness can be obtained, it is of course, to be used in preference to muslin. Three separate sieves may be used, or, for portability, it is easy to construct one, so that the gauze discs can be removed, and successively replaced in the same frame. Only a single disc should be used at a time, and no attempt should be made to sift a soil from which the impalpable portion has not been removed, or to wash any of the gradations on the gauze discs.

The dried coarse matter is carefully brushed from the filter paper into sieve No. 1., (that of the largest mesh) and sifted; what is retained is to be regarded as *small stones*. All that passed through No. 1. is put into No. 2 and sifted, the portion retained is called *grit*. The portion retained by No. 3 is considered *sand*, and all that passes through No. 3 is reckoned *fine sand*. These four portions are separately weighed, and if the sifting has been dexterously performed, the sum of their weights should come within a trifle of the gross weight obtained after drying.

On comparing the relative proportions of impalpable matter, fine sand, sand, grit, and small stones, we are prepared to form a pretty accurate estimate of the *texture* of the soil, and to draw the numerous practical inferences that depend on texture.

Examination of the Small Stones, Grit, and Sand.—To determine the mineral species that constitute the rough portion of the soil, is a point of considerable importance. For, when we know this, we have merely to refer to works on Chemical Mineralogy, to ascertain the substances of which these species are composed, and hence to learn:

1st. What substances are to be looked for in examining the impalpable portion of the soil, when, as frequently happens, that portion has arisen simply from the comminution of minerals of the same kind as the larger parts, and

2d. What are the inorganic resources of the soil, or what substances it is capable of affording to plants, as decomposition of the larger parts gradually takes place.

By ascertaining the mineral species, we are saved an analysis of the rough part—a thing, indeed, seldom attempted—but which could not be done without reducing the whole to very fine division of parts. To regard

as silica all the coarse parts that are not acted on by muriatic and sulphuric acids, as is often done, is obviously inaccurate.

To a mineralogist, the recognition of the mineral species constituting the grit, sand, &c., is by no means difficult. First, the more obvious physical characters are ascertained, by examining portions of each of the gradations under a good lens, or magnifier, increasing the power for the fine sand. Next, the hardness may be tried; and lastly, the behaviour of the different species before the blow-pipe, either alone, or with the usual fluxes. Quartz, for instance, will have a vitreous lustre, will scratch glass, and the knife will leave on it a steel-grey streak; it will be infusible *per se,* but fusible with carbonate of soda into a transparent bead. Mica plates will generally, after heating, present the appearance of golden-yellow elastic spangles, capable of being split. Felspar will be softer than quartz. The knife will scratch it with difficulty. Alone, it will fuse only on the sharp angles, but with carbonate of soda, it will fuse into a vesicular glass, or with borax, into a transparent bead. Calcareous sand, or grit, will be very readily scratched, will effervesce with acids, will calcine and become highly luminous before the blow-pipe, after which, when moistened on grey litmus paper, it will communicate a blue stain.

It would be tedious to enter into greater detail on this subject. It has already been stated that, to any one acquainted with mineralogy, it will present few difficulties. The student will succeed best by following the directions given in CAMPBELL'S translation of "*Von Kobell's Instructions for the Discrimination of Minerals by Simple Chemical Experiments.*"

Determination of the Percentage of Lime in the Coarser parts of the Soil.—It is sometimes desirable to determine, in a general way, the quantity of lime existing in the rough portion of the soil, in the condition of limestone. This may be done by operating on the coarse portion as a whole, before sifting; but as it is of considerable importance to know the state of division of the calcareous matter, it is better to operate on the small stones, grit, sand, and fine sand separately, particularly the sand and fine sand.

Any convenient quantity (say 50 grains) of the portion to be tried, is carefully weighed, and treated in the cold with diluted muriatic acid. After standing for some hours, and having been well stirred at invervals, the acid must be ascertained, by test paper, to be in excess. The solution is now separated from the insoluble residue by filtration through a weighed filter, and the filter is washed entirely free of acid, dried, and weighed. The loss in weight, after subtracting the weight of the filter, indicates the quantity of matter dissolved. If the effervescence, on first adding the acid, was considerable, and if the solution is nearly colourless, the loss may be considered as almost entirely carbonate of lime; and if an approximate estimate only is required, it may be so put down, but if greater accuracy is desired, it is necessary to separate the lime from the small portions of iron, alumina and phosphoric acid, magnesia and manganese, that have been dissolved along with it.

For this purpose, ammonia is added in excess to the filtered solution, and a precipitate falls, consisting chiefly of oxide of iron, alumina, and phosphoric acid. This precipitate is separated by filtration, and washed till the water that has passed through ceases to give a white cloudy precipitate when mixed with a solution of nitrate of silver. The solution may contain lime, magnesia, and oxide of manganese, and to separate and estimate the lime, the following steps are taken.

To the solution which will be found to contain free ammonia, muriatic acid is added till it gives but a very feeble alkaline reaction. Oxalate of

ammonia is then added, as long as it continues to produce milkiness in the solution. The milky precipitate is oxalate of lime, and as it cannot be separated from the solution when recently precipitated, on account of its tendency to run through the pores of the filter paper, it is set aside in a warm place to subside. The best method is to place it on the warm sand-bath at night, and in the morning it will be ready for filtration. Previous to filtration, the solution must be ascertained to be either alkaline or neutral. The filtration is, of course, effected through a weighed filter, and the precipitate is washed with distilled water till no residuum remains, when a drop of the water that has passed through is evaporated to dryness on a slip of platinum foil; the precipitate is then dried.

The lime may be estimated as carbonate, or as quick lime; but the former is more convenient and requires less heat. For this purpose, the dried filter paper and precipitate are put into a platinum crucible and heated to *dull* redness over the spirit lamp with double air current, or the gas furnace, air being freely admitted into the crucible to burn off the carbon, both of the oxalic acid and the filter paper. The residue will at first appear of a grey colour, but by continuing the heat, this will be got rid of. The heat is then discontinued, and, when cold enough, the crucible and its contents are weighed. To make sure, however, that none of the lime is caustic, after weighing, the powder in the crucible is moistened with a few drops of a strong solution of carbonate of ammonia, and again slowly heated to a very dull red, after which it is again weighed. A correspondence between the two weights shews, that previous to the first weighing, no carbonic acid was lost; but if the second weight exceed the first, it is the second that is taken as the true estimate. After deducting the weight of the crucible, and of the filter-ash, the remainder is the weight of carbonate of lime contained in the portion of grit or sand operated on. A comparison of this weight with the loss of weight ascertained, after treating the rough portion with diluted muriatic acid, will shew the amount of the other substances dissolved by the acid, but as their quantity is in general small, and as the object in what is called a *Mechanical Analysis* is merely to approximate to the amount of calcareous matter present, it will in general be sufficient to determine merely the amount of matter taken up by the diluted muriatic acid, and to reckon that, as exceeding by a little, the quantity of carbonate of lime present.

Organic Matter in the Rough Portion of the Soil.—If the soil, as generally happens, contains roots and other portions of plants, not broken down and decomposed to such a degree as to appear among the impalpable portion, they will be found among the different gradations of rough matter separated by the sieves. Should the operator think it necessary to estimate their amount, it may be done by igniting the whole coarse matter previous to sifting, and determining the loss of weight. Or each of the graduated portions may be ignited separately. These partially decomposed portions of plants add to the absorbing power of the soil, and, to a considerable extent, modify its texture.

Estimation of Organic Matter in the Impalpable Portion.—A convenient quantity, say 50 grains, of the dry impalpable matter of the soil is carefully weighed in a platinum crucible or capsule, (Figs. 17 and 20, page 95), and ignited, with free access of air, till the organic matter is burnt off, and this is known to be accomplished when all blackness has disappeared from the mass. When the crucible is cold, the loss of weight is determined. It expresses the weight of organic matter present, and is often, although inaccurately, called humus. Of course, the fixed inorganic

constituents of the organic matter remain, diminishing the true estimate by a very small quantity: but this is more than counterbalanced by the loss of water held in combination by the clay, which the previous drying of the impalpable matter at 300° F. had failed to drive off, but which now escapes during the ignition.

Estimation of Carbonate of Lime in the Impalpable Portion.—A weighed portion of the ignited impalpable matter is now treated with diluted muriatic acid, in the same manner as was described, page 135, in estimating the calcareous matter of the coarser parts. In this case, however, it would be more unsafe to consider the portion soluble in diluted muriatic acid, as representing the carbonate of lime present. Hence, it is necessary to separate the lime as oxalate, and to determine the percentage of carbonate directly, and with the precautions already specified.

Statement of the Results —The process being concluded, the necessary calculations are made, and a tabular statement is drawn up, embracing the following estimates :—

A.—Water in 100 parts of air-dried soil.
B.—Soluble matter.
C.—Coarser parts, consisting of :—
- *a.* Small stones—naming the mineral species.
- *b.* Grit do. do. do.
- *c.* Sand do. do. do.
- *d.* Fine sand, do. do.
- *e.* Calcareous matter in the whole, or in each of the above gradations.
- *f.* Roots and fragments of plants in the whole, or in each of the above gradations.

D.—Impalpable matter—consisting of :—
- *a.* Organic or humous matter.
- *b.* Calcareous matter.
- *c.* Inorganic matter.

Such an examination of a soil, will be found of considerable value, in the absence of a more elaborate analysis; and as it is comparatively easy, it is the sort of examination most frequently attempted by amateurs and beginners, who would shrink from more exact and complicated investigations. In cases too, where, over a considerable area, the soil has had a common and pretty uniform origin, and where a few accurate analyses of characteristic specimens have been made, these mechanical analyses will be greatly enhanced in value.

CHEMICAL ANALYSIS OF SOILS.

Considerable difference of opinion exists among writers on the subject of analysis of soils, arising, no doubt, from the want of accurate researches regarding the organic part of the soil, and the changes that are constantly going on in it; from the different views that have been taken of the nutrition of plants, and the functions of the soil; from the want of precise information regarding the inorganic constituents of plants; and from the very limited number of accurate analyses of soils that have hitherto been published. While so much remains to be done, it is vain to look for unexceptionable formulæ.

Some chemists analyse the whole soil, while others submit to minute analysis, only the portion soluble in water, and the finely divided or impalpable portion of the insoluble part. The latter method was generally

practised by Davy; and although not so generally followed now, I have seen no reason to abandon it.

It has been shewn in the preceding pages, that the coarser part of the soil, can be separated and examined, so as to ascertain the minerals of which it consists; and, when this is done, we have a better idea of its constitution, than could be got by an analysis, which, after all, would be but an analysis of mixed species, and which could not be well performed, without reducing the matters operated upon to very fine division of parts. When an accurate analysis of the impalpable portion of the soil is accompanied by such an examination of the coarser parts as has already been recommended, the objections usually adduced against this method lose their force. There is reason to believe, that the inorganic matter taken up by plants, so far as it comes from the purely mineral part of the soil, is derived, principally, from the finely divided portion, and that the nutritive matters, both organic and inorganic, derived from vegetable and animal bodies in the soil, are also supplied most freely from such as are in fine division of parts, intimately mixed with the soil, and undergoing decay. In the following pages, then, it is assumed, that the portions operated upon, with the exception of the portion soluble in water, are of the finely divided matter, separated from the coarser parts by suspension in water, as specified in the mechanical examination.

In all cases, an exact quantitative analysis must be preceded by a qualitative examination; that is to say, it must be ascertained what substances are present, before a plan for determining the exact quantity of each can be sketched.

QUALITATIVE EXAMINATION OF THE SALINE MATTERS OF THE SOIL, SOLUBLE IN WATER.

Preparation of the Solution.—Many of the saline substances being present in but small quantity, it is necessary to operate on a considerable portion of soil, to secure a solution in which their presence can be readily recognised. It is advisable also to do so for another reason, namely, to obtain a considerable quantity of washed impalpable matter, to be used in the quantitative analysis.

In this process, Sprengel recommends the treating of the soil with cold water, as more analogous to what occurs in nature; and it is, no doubt, of importance to know what rain water would likely dissolve out of the soil, but the advantages attending the use of hot water more than counterbalance this.

A quantity of air-dried soil, not less than a quarter of a pound, is broken down with the fingers, till no large lumps exist in it, and introduced into a flask or capsule, containing as much boiling distilled water as will cover the soil to the depth of an inch or two. It is boiled for twenty minutes, with frequent stirring, and then allowed to subside, after which, the supernatant water is poured on a filter, and if the first portions pass through muddy, they are returned till all that passes is quite clear. The soil is treated with fresh portions of hot water, till all soluble matter is removed from it; and this is ascertained to have been effected, when a drop or two of what passes through the filter leaves no stain, when evaporated to dryness, on a slip of platinum foil. If the soil contains gypsum, the process is tedious, but it is necessary to dissolve it out, both because it is soluble in water, and for simplifying the other parts of the process.

As the first washings contain by far the largest quantity of soluble matters, they alone should be employed in the qualitative examination;

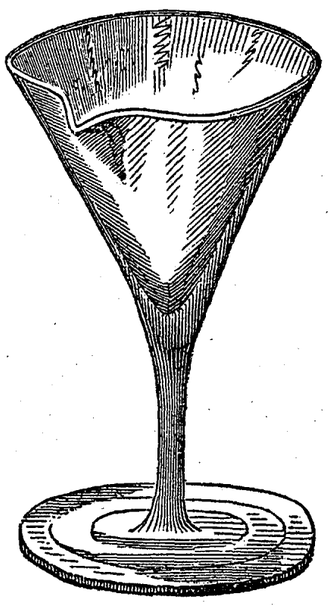
or the whole may be mixed together and concentrated by evaporation in a porcelain capsule; but either the concentration should not be carried so far as to produce a deposit from the solution, or the deposited matter should be separated by filtration, and separately examined.

When the solution, as is often the case, contains but little organic matter, the testing for soluble saline substances may be immediately proceeded with; for although organic matter does interfere with the action of some of the reagents to be employed, when it is present only in small quantity, this interference will not be of great consequence. When, however, the dark colour of the solution indicates the presence of much organic matter, it is necessary to destroy it before proceeding with the testing. For this purpose, the solution is evaporated in a porcelain capsule, till it becomes of syrupy consistence; after which, it is transferred to a platinum crucible and evaporated to perfect dryness. The crucible is then heated to incipient redness, and continued in that state till all organic matter is burnt off, and the contents lose their blackness. It is to be kept in mind, however, that if the solution contained volatile substances, such as nitric acid or ammoniacal salts, they are entirely dissipated in this process, and must be tested for in a portion of the solution reserved for the purpose, and not evaporated to dryness and ignited. It is also to be observed, that the heat is kept as low as possible during the burning off of the organic matter, to avoid, as far as it can be done, the loss of chlorides, which are almost invariably present, and are liable to be volatilised at high temperatures.

After the organic matter is destroyed, the residuum is treated with distilled water, to which a little nitric acid has been added; and if a small portion of insoluble matter still remains, it is silica, and may be separated by filtration. The slightly acid solution is now rendered exactly neutral by ammonia, or as nearly so as can be effected without causing precipitation; and thus prepared, the saline solution, which contained much organic matter, is ready for being tested.

The operation of testing is carried on in wine glasses, or small conical test glasses, (Fig. 29,) unless otherwise specified. For each trial, a small quantity of the solution (about 60 grains) is taken, and the reagent is added in quantity corresponding to its strength, and to the concentration of the solution. After the addition of the test, the mixture is shaken, or stirred with a glass rod.

Fig. 29.



Trial of Acidity or Alkalinity.—This is to be done by dipping a grey litmus-paper into that portion of the solution first obtained, for the more diluted portions cannot be expected to give a decided reaction. The solution obtained, in cases where it has been found necessary to destroy the organic matter, must, of course, be acid, from the nitric acid used in the process. The most useful litmus paper is prepared by staining the surface of perfectly pure drawing paper, (Harding's), with an infusion of litmus, to which as much nitric acid has been added, as to change its blue to neutral-tint. If the colour of the neutral or grey tint is changed to red, the indication is acid, if to blue, it is alkaline. The saline solution is generally neutral, but occasionally otherwise.

Detection of Nitric Acid.—It is very seldom, indeed, that soils in this

country contain nitrates in any appreciable quantity Even in cases where nitrate of soda has been used as a manure, so soluble is the salt, and so small a dose is required, that unless the specimen of soil were taken soon after its application, nitric acid could not readily be detected in it

If, on evaporating a portion of the solution to dryness, and heating nearly to redness, as directed for the destruction of organic matter, that peculiar mode of combustion, called *deflagration*, takes place, it arises from the presence of nitrates. This proof of the presence of nitrates, however, cannot be implicitly relied on, for the presence of common salt often renders the deflagration so slow and inconspicuous that it can readily escape observation.

The presence of nitrates may also be detected by evaporating a portion of the solution to dryness, and adding sulphuric acid and solution of sulphate of iron, when the solution assumes a brown tint, more or less deep, according to the quantity of nitric oxide evolved.

Detection of Ammonia.—A portion of the first washings, concentrated by evaporation if necessary, is transferred to a small test tube, and a few drops of a solution of caustic potash are introduced by a small funnel, to avoid soiling the mouth of the tube. The tube is then heated, while a grey litmus-paper is held within its mouth If ammonia is present, the test-paper will become blue, and after being exposed to the air for some time, or gently heated, the blue tint will disappear The smell of amonnia is so peculiar, that it forms an excellent indication of its presence; but ammonia may be detected by the means above mentioned, when present in too small quantity to be recognised by the smell.

Detection of Sulphuric Acid —To a portion of the solution, a few drops, of nitric acid are added, and then solution of nitrate of baryta. If a white precipitate is formed, the presence of sulphuric acid is indicated

Detection of Chlorine —To a portion of the solution, a few drops of nitric acid are added, and afterwards solution of nitrate of silver. When chlorine is present, a white curdy precipitate falls This precipitate becomes dark on exposure to light. Chlorides are very rarely absent, but it should be observed, that after the addition of nitrate of silver, a solution in which a white haze was barely perceptible at the time, will become dark on exposure to light if organic matter is present

Detection of Carbonic Acid —If the solution has given an alkaline reaction, the presence of carbonic acid may be inferred. If the quantity of carbonates is considerable—and this is very rarely the case—effervescence will take place, when a portion of the concentrated solution is poured into a glass containing muriatic acid. When the quantity of carbonates is small, no effervescence is perceptible, the carbonic acid being retained in solution.

It is to avoid the interference of carbonic acid, that it is necessary to acidulate with nitric acid before testing for sulphuric acid or chlorine.

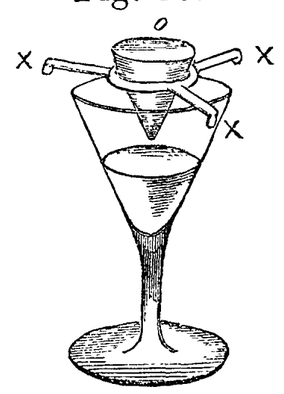
Remarks on the Subsequent Testing —Several of the substances next to be tested for might be easily detected by simple operations on separate portions of the saline solution; but as some of the number cannot be detected till after the removal of others, it becomes necessary to follow a particular order; taking those first, whose removal is required for the detection of those that follow. As some of the substances do not always occur, and when they do, only in small quantity, it is better to operate on a considerable portion of the solution; and as several of them could readily escape observation in the presence of much organic matter, it is safest to

use a portion of solution, freed from organic matter in the manner before described (page 139)

If the previous examination has shewn the presence of more than a trace of sulphuric acid, as much chloride of barium is added as is sufficient to precipitate all the sulphuric acid and no more, and the sulphate of baryta is separated by filtration Ammonia is then added to the filtered solution in excess, and from the appearance of the precipitate thereby produced, some information will be obtained regarding the kind of bases present. If the precipitate is dark brown, peroxide of iron is present; and if, on exposure to the air, the colour becomes darker, it is owing to the presence of manganese. If the precipitate is white and gelatinous, it is due to alumina or magnesia, or both; but it may have a colour more or less deep when all the four are present

Detection of Peroxide of Iron —To the solution containing the above more or less brown precipitate, muriatic acid is added till the precipitate is completely redissolved, and excess of ammonia is again added If magnesia and oxide of manganese were present, they now remain in solution, and the precipitate that falls consists of peroxide of iron and alumina—supposing both to be present This precipitate is separated from the solution by filtration, which should be conducted as quickly as possible, and after being washed it is treated on the filter-paper with muriatic acid, while still moist, whereby it is dissolved; the solution is received in another glass, and the filter-paper is washed clean.

Fig. 30.



These small filtrations are most conveniently performed by means of small and thin filter-papers, set in Clark's filtering rings, Fig 30, × × × the ring supported on the edges of the test-glass, *o* the filter-paper. It is a still better arrangement when the ring is supported by a single arm fixed in a separate stand, at such a height, that the apex of the filter is in contact with the inner edge of the test glass

To the acid solution of peroxide of iron and alumina, caustic potash is added, which at first precipitates both bases, but on being added in excess, redissolves the alumina, leaving the peroxide of iron Water is now added lest the caustic alkali should corrode the filter-paper, and the peroxide of iron is separated by filtration

Detection of Alumina —To the alkaline solution filtered from the peroxide of iron, muriatic acid is added till it is neutral; on the addition of ammonia, alumina is precipitated as a white gelatinous hydrate

Should phosphates exist in the saline solution,—and nothing beyond *traces* are likely to be met with—both the peroxide of iron and alumina will contain phosphoric acid This, however, is of no importance in a qualitative analysis, where the object is merely to ascertain what bodies are present, as a separate process for detecting phosphoric acid must be had recourse to

Detection of Oxide of Manganese —To the alkaline solution out of which peroxide of iron and alumina were precipitated, muriatic acid is added till neutral, after which, on the addition of hydro-sulphate of ammonia, sulphuret of manganese falls as a flesh-coloured precipitate Should the quantity of sulphuret of manganese be small, the characteristic colour will not become apparent till the precipitate has completely subsided, and can be viewed without the intervention of the liquid coloured by excess of the test. For the sake of beginners, it may also be mentioned, that the pre-

cipitate is not contaminated, although, on exposure to air, its colour changes to brown; for this arises from the oxidation of the manganese.

Detection of Lime.—The solution, filtered from the sulphuret of manganese, is acidulated with muriatic acid, and heated till it ceases to smell of sulphuretted hydrogen. If, after this, the solution appears muddy, it arises from precipitated sulphur, and it must be freed from this by filtration. The filtered solution is now rendered in the feeblest degree alkaline by ammonia, and oxalate of ammonia is added in excess, whereby a white precipitate of oxalate of lime is produced, either immediately, or after standing for some hours, according to the quantity of lime present. This precipitate, as already mentioned, is very liable to run through the filter paper; hence, any attempt to filter, before it has stood for some hours in a warm place, will be unsuccessful.

Detection of Magnesia.—The solution filtered from the oxalate of lime, is concentrated by evaporation, in a porcelain basin, till it is reduced to a small bulk; after which, it is completely transferred to a platinum crucible or capsule, and cautiously evaporated to dryness. It is next heated to *dull* redness, to drive off volatile substances, and the heat must be so regulated as to occasion no loss. The saline residuum is dissolved in a small quantity of water; and if any thing insoluble remains, it may be taken up by a few drops of muriatic acid, and added to the aqueous solution. Pure red oxide of mercury (red precipitate free from nitric acid, and all basic impurities) is added to the solution, and the whole is evaporated to dryness. On treating the dry mass with water, magnesia and the excess of oxide of mercury remain undissolved: they are separated by filtration, washed, and ignited, to drive off the oxide of mercury. The white powder which remains is magnesia.

Detection of Potash and Soda.—The solution, filtered from magnesia and oxide of mercury, is evaporated to dryness and ignited: chlorides of potassium and sodium alone remain. A small portion of the saline mass is taken up on a scrupulously clean platinum wire, curved at its extremity, so as to retain the assay, and heated in the apex of the reducing flame of the blowpipe. If soda is present, the outer flame is coloured of a fine yellow tint, remarkably apparent in the portion of the oxidating flame, which is colourless, or faintly blue, when no assay is held in the point of greatest heat.

The saline mass is now dissolved in a *small* quantity of water, and a strong aqueous solution of tartaric acid is added If a crystalline precipitate falls immediately, or on standing, and after frequent stirring, potash is also present. [I have examined no specimen of soil from which potash was entirely absent.] In place of tartaric acid, chloride of platinum may be employed, which gives a yellow precipitate when salts of potash are present.

A method of precipitating soda has recently been proposed by M. Fremy, which is capable of detecting the $\frac{1}{350}$th of a salt of soda in a mixed solution of soda and potash salts. Although the blowpipe test above mentioned is quite conclusive, it may be satisfactory after the precipitation of potash by tartaric acid, to obtain evidence of the presence of soda by precipitation. For this purpose, the solution filtered from bitartrate of potash, is rendered exactly neutral by solution of pure caustic potash, and again filtered from bitartrate, after which, solution of antimoniate of potash is added, which, if soda is present, will, either immediately, or after stirring, throw down a crystalline precipitate very similar in appearance to bitartrate of potash; it is antimoniate of soda.

Detection of Phosphoric Acid.—The soluble saline matter of the soil rarely contains more than traces of phosphoric acid, and in many cases no phosphoric acid can be detected. Such, however, is the importance of this substance as a constituent of plants, and consequently of soils and manures, that careful search should be made for it even when present only in traces. Sprengel states that when peroxide of iron and alumina are present, only traces of phosphoric acid can be met with.

For the detection of phosphoric acid, a separate portion of the aqueous saline solution is necessary; and the organic matter should be destroyed. If peroxide of iron or alumina was found in the previous examination, no addition is necessary; but if they were absent, or occurred merely as traces, a few drops of permuriate of iron are added to the solution. Ammonia in excess is next added, and the precipitate is separated by filtration, washed, and treated on the filter-paper with concentrated acetic acid. The soluble matters are taken up by the acetic acid, and pass through the filter; while the phosphate of iron and phosphate of alumina remain upon it undissolved. As, however, traces of these substances might easily remain on the filter-paper unobserved and scarcely appreciable by the most accurate weighing, it is better to throw down the precipitate by ammonia, in a tall narrow test-glass, (Fig. 31,) and to wash it by affusion and subsidence; that is, as soon as the precipitate has subsided, to pour off or draw off by a syphon, or a sucker, (Fig. 32,) as much of the supernatant liquid as can be done without loss of the precipitate. After this, the vessel is filled up with distilled water, and the precipitate is well stirred up. After subsidence, the clear water is again drawn off, and this process is repeated till the precipitate is washed clean. When this point has been attained, and the wash-water as completely removed as possible, the precipitate is digested in strong acetic acid: if any portion of the precipitate remains undissolved, phosphoric acid is present.

Fig. 31.

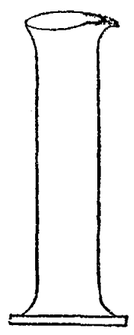
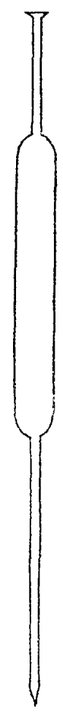


Fig. 32.



In the foregoing qualitative examination, no notice has been taken of substances that very rarely occur, such as oxide of copper, baryta, &c. The methods by which they may be distinguished and separated from other bodies may be readily ascertained by reference to works on chemical analysis.

Every conclusion arrived at in the qualitative analysis, should be carefully noted down at the time; and when the investigation is at an end, the operator will be in possession of data, from which, it is easy to draw up a scheme of quantitative analysis, with no more complication than is absolutely necessary for the estimation of the bodies actually present.

QUANTITATIVE ANALYSIS OF THE SALINE MATTER OF SOILS SOLUBLE IN WATER.

For the quantitative analysis, a solution is to be prepared from a known weight of air-dried soil; and this weight will be regulated by the quantity of saline matter present, a pretty accurate idea of which will have been obtained in performing the qualitative analysis. To obtain weighable quantities of some substances that may be present in very small proportions, Sprengel recommends as much as two pounds of soil to be operated upon; but a half, or even a fourth of this quantity, will in most cases suffice; but whether a large or small quantity has been employed, it is

always necessary, in stating the results, to mention the exact weight of soil from which the saline solution has been obtained, In preparing the solution, care is to be taken that every thing soluble is taken up, and that no clay, or finely divided solid matter passes through the filter.

Determination of the Amount of Soluble Matter.—A portion of the filtered solution is poured into a porcelain evaporating basin, and evaporated to a small bulk. A second portion is then added, and the evaporation is carried on till the whole solution is reduced to a very small bulk. The concentrated solution is carefully transferred to a weighed platinum crucible, and cautiously evaporated to dryness. After being heated in the bath at 300° F. till it ceases to lose weight, it is weighed.

Small portions of very volatile matter may escape, but the organic matter present would not at a lower temperature be sufficiently dry.

Estimation of Bodies Destructible by Heat, such as Organic Matter, Nitric Acid, and Ammoniacal Salts.—These substances, the presence of which will have been previously ascertained, are generally estimated together; but it is not often that nitrates or ammoniacal salts will be found in appreciable quantity. The crucible containing the dry weighed saline matter is gradually heated to incipient redness, and kept so till the organic matter burns away; which is ascertained by the heated mass becoming light in colour. The crucible is again weighed, and the loss reckoned as organic and volatile matter.

Estimation of Ammonia.—If in the qualitative examination it has appeared, that ammoniacal salts are present in quantity sufficient to render it necessary to estimate the ammonia, it is done as follows:—A quantity of the saline solution corresponding to a known weight of soil is taken, and if alkaline, neutralised with muriatic acid and evaporated to a small bulk. It is next transferred to a tubulated retort of suitable size, which is adapted to a close receiver containing dilute muriatic acid. Through the tubulature of the retort there is passed, by means of a perforated cork, a tube-funnel reaching nearly to the bottom of the retort, and drawn to an almost capillary point. When the apparatus is adjusted, a strong solution of caustic potash is introduced by means of the tube-funnel, and heat is applied. The ammonia is set free by the potash, and passes over into the receiver, where it is condensed by the muriatic acid. When all the ammonia has passed over, the receiver is detached, and its contents are transferred to an evaporating basin, and evaporated to a very small bulk; after which, the concentrated solution is carefully washed into a weighed platinum crucible, and evaporated in a water bath to dryness. It is then weighed, and returned to the water bath for some time, and again weighed. If the two weights agree, the process is at an end; if not, the heat is continued till the loss of weight ceases. The weight of sal-ammoniac multiplied by ·320142 gives the weight of ammonia in the quantity of solution operated upon.

If the exact quantity of dilute muriatic acid used for condensation is known, and if at the same time it is perfectly pure, and its neutralizing power accurately ascertained, the quantity of ammonia may be determined by ascertaining how much of an alkaline test solution is required to neutralize the remainder. Indeed, with a little experience, this method is not only the simpler, but the more accurate way of estimating the quantity of ammonia.

Estimation of Silica.—After the weighing by which the organic and volatile matter has been determined, the contents of the crucible are to be treated with a few drops of nitric acid, and then with water, heat being

at the same time applied; when, if any thing remains undissolved, it is silica, and is to be separated by filtration on a weighed filter, washed, dried, and ignited with the filter-paper in an open platinum crucible, weighed, and the weight of the filter-ashes subtracted.

The solution, filtered from the silica, may now be evaporated to dryness, and divided into as many equal portions as the operator requires for estimating the various substances known to exist in it; or, without evaporating to dryness, it may be carefully divided either by weighing or measuring.

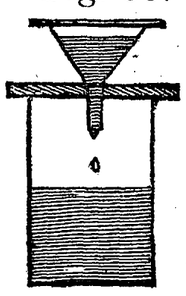
Estimation of Sulphuric Acid.—To one of the portions of the solution, slightly acidulous, from the presence of a little free nitric acid, solution of nitrate of baryta is added as long as a precipitate falls. The whole is then gently heated, and the precipitate after being allowed time to subside, is separated by filtration upon a weighed filter. After this it is washed, dried, and ignited; but the heat should be no higher than is necessary for the complete combustion of the paper. The weight of the sulphate of baryta is then ascertained, that of the filter ashes being deducted. The weight of sulphate of baryta multiplied by ·34332 gives the weight of sulphuric acid found.

Estimation of Chlorine.—To the solution, filtered from the sulphate of baryta, solution of nitrate of silver is added as long as a precipitate falls. To facilitate the filtration, the whole is boiled for a few minutes, and then filtered, washed and dried. Having been carefully removed from the filter-paper, the chloride is fused in a small porcelain capsule and weighed, the filter-paper having been burnt to ashes on the lid of the crucible, and its ashes added to the chloride.

The weight of filter-ash having been deducted, the weight of fused chloride multiplied by ·24695 gives the weight of chlorine found.

Estimation of Oxide of Iron.—The solution, filtered from the chloride of silver, contains a little nitrate of silver and nitrate of baryta added in excess, in precipitating chlorine and sulphuric acid. To remove the silver, a little muriatic acid is added, and to remove the baryta, a little sulphuric acid. The mixture is heated, the precipitates are separated by filtration, and the filter washed free from the solution. Ammonia is now added to neutralize the free acid, whereby as much ammoniacal salt is generated as prevents the precipitation of manganese and magnesia, when excess of ammonia is added to throw down the oxide of iron and alumina, (page 141). The oxide of iron and alumina are collected on a filter and washed. During the filtration, the air is to be excluded as much as possible, by a plate of glass laid across the mouth of the funnel, (Fig. 33.)

Fig. 33.



The oxide of iron and alumina are now dissolved off the filter-paper by muriatic acid, (page 141,) and the filter is washed clean. Both bases are thrown down by caustic potash, and excess of the precipitant is added to dissolve the alumina. The oxide of iron is then separated by filtration on a weighed filter, washed, dried, ignited with free access of air, and weighed.

Estimation of Alumina.—To the alkaline solution filtered from peroxide of iron, muriatic acid is added till it is neutral or feebly acid, and then solution of carbonate of ammonia, whereby the alumina is thrown down, but not entirely free from potash. The precipitate is freed from the solution by filtration, and washed. It is dissolved off the filter-paper by muriatic acid; the filter is well washed, and the alumina is again precipitated by carbonate of ammonia, and well washed on a weighed filter.

The alumina is now pure, and is to be thoroughly dried, heated to whiteness, weighed, and the weight of the filter ashes deducted.

It has already been mentioned, that traces of phosphoric acid may occur along with the oxide of iron and alumina.

In many cases the quantity of oxide of iron and alumina found in the saline solution extracted from the soil by water, is so small, that the two substances may be estimated together.

Estimation of Lime.—To the solution from which the oxide of iron and alumina were precipitated by caustic ammonia, oxalate of ammonia is added, whereby the lime is precipitated as oxalate of lime. After standing in a warm place for twelve hours, the precipitate is separated by filtration, washed, dried, ignited, and estimated, with the precautions already specified, (page 136). After deducting the weight of the filter-ash, the weight of the carbonate of lime multiplied by ·56657 gives the weight of lime present.

Estimation of Oxide of Manganese.—To the solution filtered from the oxalate of lime, hydro-sulphate of ammonia is added, whereby sulphuret of manganese is precipitated. The precipitate is separated by filtration, and washed with water, to which a little of the precipitant has been added. It is, while still moist, dissolved off the filter-paper by muriatic acid, and the filter-paper is washed till the water that passes through ceases to give an acid reaction. If the solution smell of sulphuretted hydrogen, it is boiled till it ceases to do so, and any deposit of sulphur is separated by filtration. To this acid solution, placed in a small porcelain evaporating basin, solution of carbonate of potash is added in excess, and the whole is evaporated to dryness, but carefully, to avoid spurting. Hot water is next added, by which the soluble parts are taken up, and insoluble carbonate of manganese remains. This precipitate is collected on a weighed filter, washed, dried, and ignited in an open platinum crucible, at a full red heat, whereby it is converted into red oxide of manganese. It is then weighed, and the weight of the filter-ash being subtracted, the weight multiplied by ·93049 gives the weight of protoxide of manganese present in the portion of solution operated on.

Estimation of Magnesia.—For the estimation of magnesia and the fixed alkalies, it is best to employ a separate portion of the dry saline matter, or of the saline solution. Magnesia is most readily separated from the alkalies by the method of Berzelius; but for this purpose they must exist as chlorides. Hence, if sulphuric acid is present, it is to be removed by adding just as much chloride of barium as is necessary to precipitate the whole sulphuric acid present, and no more; and this is effected by using the precipitant pretty dilute, and adding but a little at a time, particularly towards the close. An excess of chloride of barium is to be avoided, from the trouble it gives to separate it without the use of sulphuric acid. The bases present, except magnesia and the alkalies, are next removed, and by the processes already given; but as much in mass as possible: thus, in separating the foregoing bases for estimation, every precaution has been recommended to be taken to ensure their purity and accurate separation; now, however, it is desirable to cause them to fall together, to shorten the process, and save trouble; but in doing this, no step is to be taken that would risk the loss of a particle of magnesia or the alkalies.

After the separation of the bases already treated of, the solution containing the magnesian and alkaline chlorides is concentrated by evaporation, and transferred without loss to a platinum crucible, in which, after

the evaporation is carried to dryness, the residuary saline mass is gradually heated to dull redness, to drive off all volatile matter. The chlorides are now dissolved in a small quantity of water, and if a portion of the magnesia remain insoluble from the loss of acid, it is taken up by a drop or two of muriatic acid and added to the rest. Excess of pure red oxide of mercury is next mixed with the solution, and the whole is evaporated to dryness. Water is poured on the dry mass, and after being well stirred and gently heated, it is thrown on a weighed filter and washed till chlorine cannot be detected in the water that passes through; but not longer, for magnesia is not entirely insoluble. The filter containing the magnesia and excess of oxide of mercury is dried, and ignited, to volatalise the latter and burn the paper. The remaining magnesia is weighed, and the weight of the filter-ash subtracted.

Estimation of Potash and Soda.—The solution filtered from the magnesia is now evaporated to dryness, and heated to dull redness to drive off the mercurial salt; but as the alkaline chlorides cannot be very highly heated without loss, nothing beyond a dull red is admissible, The mixed chlorides of potassium and sodium are now weighed, and in many cases it is unnecessary to do more than ascertain the weight of the two together, without separating them. If, however, the operator wishes to determine the weight of the alkalies separately, it is done as follows. The mixed chlorides, after being weighed, are mixed with 3·75 times their weight of crystallized platino-bichloride of sodium. The mixture is dissolved in a very small quantity of water, and evaporated at a low heat to dryness. On the dry mass is poured spirit of wine, of specific gravity ·896, which takes up every thing soluble, leaving platino-bichloride of potassium undissolved. It is separated by filtration, and washed with spirit of wine of the above density; after which, it is exposed to a gentle heat till it ceases to lose weight. The weight of this salt multiplied by ·19307 gives the weight of potash present, or if multiplied by ·30535 it gives the weight of chloride of potassium.

The amount of soda present is estimated by the loss. Thus, when the weight of chloride of potassium is subtracted from that of the alkaline chlorides ascertained before the precipitation of the potash, the weight of chloride of sodium is left; and this weight multiplied by ·53303 gives the weight of soda present.

Estimation of Phosphoric Acid.—Phosphoric acid is best separated by the method of Schulze already mentioned. A separate portion of the saline matter or saline solution is employed, and in quantity sufficient to afford results capable of being weighed. If iron has been found during the previous examination no addition of it may be requisite, but merely to boil the solution with a few drops of nitric acid, to secure the peroxidation of the iron. If no iron has been found, or only traces, a little acetate of peroxide of iron is added. Ammonia is next added in excess, and the precipitate after being well washed is digested in acetic acid, whereby every thing is dissolved except the phosphates of iron and alumina. These phosphates are washed, dried, ignited and weighed.

The mixed phosphates are then digested in caustic potash, which dissolves the phosphate of alumina, and the greater part of the phosphoric acid of the phosphate of iron. After dilution, the peroxide of iron is separated by filtration and washed; but as it still retains phosphoric acid, it is dissolved off the filter-paper by muriatic acid, and the filter is washed free from acid. The acid solution is neutralised by ammonia, and hydrosulphate of ammonia is added, by which the iron is precipitated as sul-

phuret. The whole is gently heated for some time to promote the entire subsidence of the sulphuret, which is known to be effected when the supernatant liquor is yellow and not green. The sulphuret is now collected on a filter, and washed with water containing a little hydro-sulphate of ammonia. When the washing is completed, the sulphuret, while still moist, is treated with muriatic acid till the iron is dissolved, and the filter-paper is washed clean. The acid solution is now heated till it loses all smell of sulphuretted hydrogen, filtered, to separate sulphur, and the filter is washed. A few drops of nitric acid are now added to the filtered solution, and it is boiled to peroxidise the iron. Ammonia is next added in excess, whereby peroxide of iron is now precipitated in a state of purity. The whole is heated to promote the separation of the precipitate, after which it is collected on a weighed filter, washed, thoroughly dried, ignited with free access of air, and weighed. The weight of filter-ash being deducted, the exact weight of peroxide of iron remains.

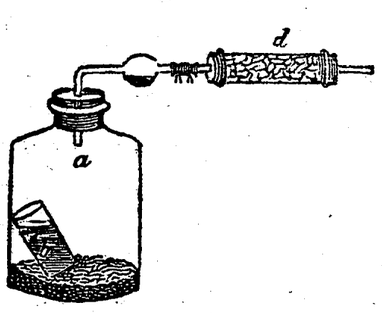
The phosphate of alumina dissolved by the caustic potash next requires to be treated, so as to separate and estimate the alumina. For this purpose, solution of silicate of potash is added to the alkaline solution, it is diluted, and the whole is boiled to promote the separation of silicate of alumina. The solution is separated by decantation, and the precipitate is thoroughly washed; after which it is treated with muriatic acid, and cautiously evaporated to perfect dryness, whereby the silica is rendered insoluble. The dry residuum is moistened with a little muriatic acid, and, after standing for some time, the soluble part is dissolved out by water, and the insoluble silica is washed on the filter-paper. The solution now contains the alumina free from phosphoric acid; it is precipitated by carbonate of ammonia, washed, thoroughly dried, ignited and weighed.

The weights of peroxide of iron and alumina thus found, being deducted from the weight of mixed phosphates ascertained near the beginning of the process, the remainder expresses the weight of phosphoric acid present; and this method of determining its weight by loss is had recourse to, because, under the circumstances, it is not possible to ascertain it directly with much accuracy.

It is obvious, that when alumina is absent, the process is much shortened.

Estimation of Carbonic Acid.—When it occurs, and it very rarely does so, that the saline solution contains carbonates, it is necessary to estimate the carbonic acid. A quantity of the concentrated solution, corresponding to a known weight of air-dried soil, is introduced into a thin flask of small capacity, (Fig. 34,) *a*. A sufficient quantity of sulphuric acid is introduced in the tube *b*, which should be long enough to be incapable of overturning, or allowing any of the acid it contains to escape, while the flask *a* stands upright. The flask is closed by an accurately fitting cork, through which a small tube passes, and the tube is connected by a caoutchouc joint with the tube *d*, which is filled with fragments of fused chloride of calcium, and communicates with the air by another small tube, drawn at its extremity to an almost capillary diameter. The apparatus being adjusted, the whole is counterpoised in a balance large enough for the purpose, and yet sensible to a very small differencc of weight. The flask is inclined so as to bring a little of the acid into the solution, and when the effervescence ceases,

Fig. 34.



another portion of acid is brought out, and so on, till the carbonate is entirely decomposed. The gas escapes through the tube, while any watery vapour that rises along with it is retained by the chloride of calcium. Heat is now applied to the flask, to expel any carbonic acid that remains in the solution; and by raising a quantity of steam, the gas that filled the apparatus is also driven off. When the operator possesses an air-pump, it is simpler, after the action of the acid has ceased, to place the apparatus under a receiver and exhaust the air; readmitting the air, however, through another chloride of calcium tube. A more convenient form of the apparatus is to have the small tube leading from the flask to the chloride of calcium tube twice bent, so that the latter stands horizontally over the top of the flask.

When the gas has been entirely expelled, the loss of weight is ascertained; it represents the carbonic acid of the carbonates present.

Statement of Results.—The quantitative analysis of the soluble saline matter being concluded, it is necessary, in stating the results, to indicate the state of combination in which the various bodies found existed in the solution; but as the remarks on this subject apply also to the statement of the remaining parts of the analysis, they are deferred till an account of the subsequent processes has been given.

ANALYSIS OF THE FINELY-DIVIDED MATTER OF THE SOIL INSOLUBLE IN WATER.

From the previous examination of the soluble matter of the soil, and particularly of the grit and sand, a good deal of information regarding the nature of the impalpable or finely-divided portion will have been obtained. The impalpable portion of a fertile soil consists of minerals in fine division of parts, more or less decomposed, mixed with organic matter, chiefly vegetable, in a state of decay. The organic matter may, and often does, demand a separate examination, chiefly with the view of ascertaining its condition; whether it is in an inert condition, as is the case with peat, or undergoing steady, though slow decay, or in any of the numerous and little investigated intermediates states. Very little accurate data yet exists on which to base such an examination; and hence, it is usual merely to estimate the amount of organic matter, or the matter destructible by a low red heat. With respect to the inorganic matter, much less difficulty exists. After destroying the organic matter, the residue will generally be found to consist of silica and silicates; of carbonates, as of lime and magnesia, that existed as such in the soil; of peroxide of iron and alumina, resulting from decomposed silicates; and of the bases that were united with the organic matters. It is desirable to ascertain the percentage of carbonate of lime in a soil, as it is known to be essential to fertility; and the same may be said of carbonate of magnesia and peroxide of iron. For this purpose, as was recommended in the mechanical analysis, the impalpable matter, after ignition, is treated with cold diluted muriatic acid, and the lime, and if necessary the magnesia and peroxide of iron are estimated. The portion left undissolved, by the diluted muriatic acid is then analysed; and the method usually followed, is to treat it first with boiling concentrated muriatic acid, and next with hot concentrated sulphuric acid; regarding the residue as silica, and difficultly decomposable silicates. In place of this method, however, it is shorter, at once to decompose the residue left by the diluted muriatic acid by ignition with carbonate of potash, only, the alkalies cannot, in this way, be estimated. Still, however, it is preferable to make a separate

process for estimating magnesia and the alkalies; and when the operator possesses the means, the hydro-fluoric acid method is employed with the greatest advantage.

Estimation of Organic Matter.—A convenient quantity, say 50 grains, of thoroughly washed and dried impalpable matter, is carefully weighed in a platinum crucible, and ignited at a very dull red, till all organic matter is burnt off, as described page 136, and the loss of weight is determined.

Estimation of Lime existing as Carbonate, or in Combination with Organic Matter.—After the destruction of organic matter, the contents of the crucible are transferred to a porcelain evaporating basin, and treated in the cold with muriatic acid diluted with three or four times its bulk of water; being frequently stirred with a glass rod, and allowed to stand ten or twelve hours. The dissolved portion is now separated by filtration, and the residue is washed free from acid, dried, ignited and weighed. The loss of weight shews how much the muriatic acid has taken up. The acid solution is concentrated by evaporation and neutralized with ammonia, and on adding a slight excess of the alkali, a precipitate is thrown down, consisting chiefly of peroxide of iron, alumina, and phosphoric acid. The precipitate is collected on a filter, protected from the air by a plate of glass, (page 145,) and washed. If now, the only thing to be estimated is lime, it is done by adding oxalate of ammonia to the filtered solution, and proceeding as already described, pages 135-6.

Estimation of Carbonic Acid.—As the lime estimated has existed partly as carbonate, and partly in combination with organic acids, it becomes necessary to estimate the carbonic acid in a known weight, say 50 grains, of the impalpable matter, in which the organic matter has not been destroyed. This is done in the same way as has been pointed out page 148, in estimating the carbonic acid of the soluble saline matter. It may be remarked, that although muriatic acid is generally employed in estimating the carbonic acid of earthy carbonates, sulphuric acid deserves in this case a decided preference; because, from the fine division of the matter operated on, there need be no fear of effecting complete decomposition; in all other respects, the advantages of sulphuric acid are manifest.

Bearing in mind that 1 of carbonic acid corresponds to 1·28842 of lime —if it appears that there is enough of carbonic acid to account for the whole lime found, then, as a part of the lime—a very small part it will sometimes be—must have resulted from the decomposition of organic matter, a part of the carbonic acid must have existed in the impalpable matter in combination with some other base as magnesia or protoxide of iron. Should the quantity of these bases prove to be appreciable, the analysis both of the precipitate thrown down by ammonia, and of the solution filtered from the oxalate of lime, may be proceeded with by processes easily deducible from what has already been stated, or from what is contained in the next section. As this, however, rarely occurs, both the precipitate and the solution may be retained, to be conjoined with the solution obtained in the following process.

Treatment with Concentrated Muriatic Acid, and Estimation of Silica and Difficultly decomposable Silicates.—The residue left undissolved by the diluted muriatic acid is transferred to a porcelain capsule, and treated for an hour, with hot concentrated muriatic acid. The heat should be continued till the whole is evaporated to dryness; the dry mass is then moistened with a little muriatic acid, and after being allowed to stand for half an hour, the soluble parts are taken up by water, and the insoluble residue is col-

lected on a weighed filter, washed, dried, ignited, and weighed: the loss of weight shows how much has been dissolved in the process. The insoluble residue is sometimes, though inaccurately, put down as silica. It no doubt consists chiefly of silica, but it almost always contains also difficultly decomposable silicates. To separate the bases of these silicates, it might, as has been mentioned, be treated with hot sulphuric acid; but as most of the silicates met with in soils, are incapable of complete decomposition, even by protracted digestion in sulphuric acid, it is best to omit it altogether; and in stating the results of the analysis, to put down the insoluble portion, as silica, and silicates not decomposable by digestion in hot concentrated muriatic acid. And this course is perhaps not unsafe, because silicates incapable of decomposition in hot muriatic acid, cannot, in an undecomposed state, play a very active part as constituents of the soil; and their decomposition, under ordinary circumstances, must be particularly slow. In an accurate analysis, however, it is necessary to complete their decomposition; and as will be hereafter shewn, this can be readily effected by fusion with carbonate of potash, or by treatment with hydro-fluoric acid.

It is necessary also to observe, that the whole silica of the decomposed silicates is not left in the insoluble portion above described; for most of the precipitates obtained, contain a very small percentage of this earth; hence, in very accurate analyses, these minute portions must be separated, estimated, and their weight added to that of the larger quantity. This is done, by dissolving the several precipitates in muriatic acid, after they have been heated to redness and weighed; the silica remains undissolved, and is to be separated by filtration, washed, dried, ignited and weighed.

Progress of the Analysis of the Substances taken up by Muriatic Acid.—If phosphoric acid is present, it exists, of course, in the precipitate thrown down by ammonia, (page 150), out of what the dilute muriatic acid took up; and if more than a trace exists, it must be removed by digesting the precipitate in acetic acid, in the manner already described; the cases are, however, extremely rare, where the quantity of phosphates occurring in 50 grains of the impalpable matter amount to as much as would render this necessary. But when it is so, the solution in acetic acid is evaporated to dryness in a platinum capsule, and ignited at a dull red heat. The residuum is transferred to a porcelain capsule, dissolved in muriatic acid, and mixed with the solution which was filtered from silica and silicates. When it is unnecessary to remove phosphates, the precipitate thrown down by ammonia out of the dilute muriatic acid solution, is simply dissolved off its filter-paper by muriatic acid, and added to the solution obtained by concentrated muriatic acid, after that solution has been filtered from silica.

To the conjoined muriatic acid solutions ammonia is added to neutralise free acid, and in slight excess to throw down peroxide of iron and alumina; care being taken, that as much ammoniacal salt is present as to prevent, so far as it can be done, the precipitation of manganese and magnesia. The precipitate is collected on a filter, protected from the air, and quickly washed. The precipitate of peroxide of iron and alumina, even when a considerable quantity of ammoniacal salt is present, falls accompanied by small quantities of oxide of manganese and magnesia; which, if the operation is to be an exact one, must be separated.

Estimation of Alumina.—The precipitate by ammonia is dissolved off the filter-paper by muriatic acid, avoiding excess of the acid, and the filter is washed clean. To the solution, placed in a platinum capsule,

solution of caustic potash is added in excess, and the whole is boiled. By this means, the alumina is taken up, while the peroxide of iron, together with the small quantities of magnesia and oxide of manganese are left. Water is added to dilute the solution, the precipitate is collected on a filter, and washed till no alkali can be detected in the water. The alumina is then precipitated, and estimated by means already pointed out, (page 145).

Separation of Peroxide of Iron from Oxide of Manganese and Magnesia.—The precipitate, separated by filtration from the alkaline solution of alumina. is, while still moist, dissolved off the filter-paper by muriatic acid, and the filter-paper is washed clean. In dissolving off the precipitate, excess of muriatic acid is employed, in order that, on the addition of ammonia, enough of sal-ammoniac may be generated, to render the subsequent separation of the iron from the manganese safe. To the acid solution ammonia is added cautiously; and that there may be no danger of supersaturation, a very dilute solution of ammonia is used towards the close; and it is also expedient to reserve the last washings of the filter, which being but very feebly acid, are to be added to the rest of the solution at the time that the very dilute ammonia is in use. It is known that exactly enough of ammonia has been added, when a slight precipitate of peroxide of iron, produced by the last added drop of dilute ammonia, does not quite dissolve when the solution is gently heated. This point being attained, the iron is precipitated by neutral succinate of ammonia, and the mixture is allowed to stand till it is completely cold. The precipitate is collected on a weighed filter, and carefully washed with *cold* water. The solution, thus separated, contains the small quantities of manganese and magnesia; and is reserved, to be treated along with the other solution containing the larger quantities of the same bases. The succinate of iron, while still moist, is treated on its filter-paper with dilute ammonia, for the purpose of removing as much of the succinic acid as possible. The filter is then dried and ignited, care being taken, that during the operation, air enters freely into the platinum crucible, to consume the remains of the succinic acid, as well as to burn the filter-paper. When the crucible is cold enough, it is weighed, and the weight of filter-ash being subtracted, that of peroxide of iron remains. When the ignition is carefully conducted, there is little danger of any portion of peroxide of iron being reduced; if, however, it so happen, and the residuum proves attractable by the magnet, it is to be redissolved in muriatic acid, and boiled. after adding a drop or two of nitric acid; peroxide of iron is then thrown down by ammonia, and estimated a second time.

Estimation of Lime.—To the solution filtered from the peroxide of iron and alumina, (page 151,) ascertained by test-paper to be very feebly alkaline, oxalate of ammonia is added; the lime is precipitated as oxalate, and is estimated as carbonate, in the manner before described. This portion of lime is to be entered in the table of results, as having existed in the impalpable matter of the soil in the state of silicate.

Estimation of Oxide of Manganese.—The solution, filtered from the oxalate of lime, is mixed with the solution formerly filtered from oxalate of lime, (page 150,) when the lime was precipitated out of the dilute muriatic acid solution. The conjoined solutions are rendered quite neutral by muriatic acid, aud hydro-sulphate of ammonia is added to precipitate the manganese as sulphuret, in the manner described page 146.

Estimation of Magnesia and the Alkalies.—The solution, filtered from sulphuret of manganese, is acidulated with muriatic acid, boiled to expel

sulphuretted hydrogen, filtered to remove sulphur, evaporated to dryness, and ignited at a low red heat to expel ammoniacal salts. After this, the magnesia and alkalies are separated and estimated in the same manner as in the analysis of the soluble saline matters, pages 146-7.

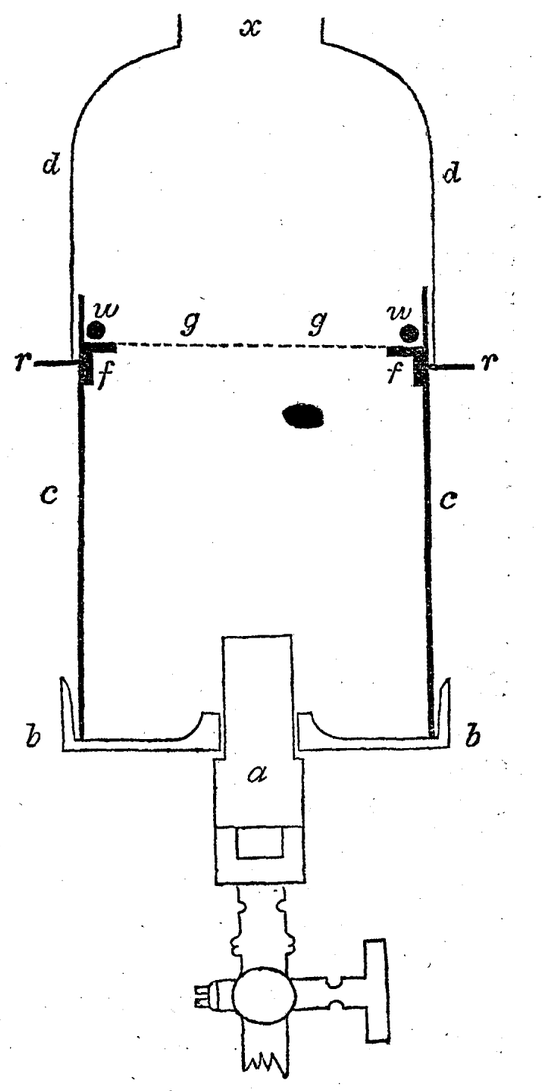
Estimation of Phosphoric Acid.—It has been already remarked, that phosphoric acid is present in the impalpable matter of soils, in quantity so small, as generally to be incapable of estimation when operating on small portions. For its estimation, a considerable quantity of impalpable matter—say 1000 or 2000 grains should be taken. It is first ignited to destroy organic matter, and then treated with muriatic acid, to which a little nitric acid has been added; the soluble parts are separated by filtration, and the filter is washed. To the filtered solution excess of ammonia is added; the precipitate thereby produced is digested in acetic acid, and the remaining parts of the process are conducted as described page 147.

ANALYSIS OF THE RESIDUUM INSOLUBLE IN HOT CONCENTRATED MURIATIC ACID, BY FUSION WITH CARBONATE OF POTASH.

The silicates, which resisted the action of hot concentrated muriatic acid, may be decomposed by fusion with carbonate of potash; only, if any potash or soda still forms part of them, it is impossible in this way to estimate these alkalies.

Before mineral substances can be decomposed by fusion with carbonate of potash, it is necessary that they be in very fine division of parts; but when the impalpable matter has been obtained in the manner before described, no part of it will be found too coarse for this mode of decomposition. The matter insoluble in hot muriatic acid is, after ignition and weighing, transferred to a larger platinum crucible, and intimately mixed with three or four times its weight of dry, powdered carbonate of potash; adding the carbonate of potash in small quantities at a time, and stirring the mixture well with a glass rod after each addition; or, the mixture may be made in an agate mortar, and to prevent loss by the adhesion of traces of the mixture to the mortar, it should be rubbed out with several, successive, small portions of carbonate of potash. The crucible containing the mixture is covered with its lid and heated, gently at first, but rising gradually to a full red, which is continued for an hour. It very rarely happens that the soil contains silicates which are not decomposable by this process.

Fig. 35.



The ignition may be effected in the furnace, or even in a common fire; but in either of these cases, the platinum crucible must be protected from the action of the fuel, by a fire-clay crucible-case, Fig. 15, page 95. When the operator has the command of coal-gas,

he will find it most convenient, in all cases where a white heat is not required, to employ the wire-gauze gas-furnace, (Fig 35) In this figure, *a* represents an ordinary 18-hole argand burner, *b b* a support consisting of a ring, with four horizontal arms, turned up at the ends, to retain in its place the sheet-iron cylinder, *c c* *f f* is a flange of sheet-iron riveted to the cylinder, for supporting a disc of wire-gauze, indicated by the dotted line *g g* *w w* is a ring of stout iron-wire to tighten the disc of wire-gauze, and keep it in its place. *d d* is a dome of sheet-copper to retain the heat. *x* the chimney through which the crucible is lowered, supported in a ring of platinum wire. *r r* tails of the rivets, or projecting pins, on which the dome is supported When this furnace is to be used, the stopcock is opened to allow a little gas to escape, and mix in the cylinder, with atmospheric air A lighted match is then applied above the wire-gauze, and the mixture burns with a pale, blue, lambent flame, quite free from smoke, provided the gas is not in too great proportion to the air. The dome is then set in its place, and the crucible suspended from a stand, is lowered through the aperture *x* When only a small quantity of gas is used, the crucible is to be lowered nearly to the wire-gauze, but, as the quantity is increased, the point of highest heat gets more elevated; hence, it is preferable to suspend the crucible, rather than set it in a common crucible jacket *

When the ignition is finished, the more or less fused mass is transferred to a porcelain capsule; but when complete fusion has taken place, it is often difficult to detach the mass from the crucible; by gently pressing the sides of the crucible, however, this can often be effected, and when it cannot, successive portions of water are introduced till it is almost all washed out, and to remove the last, and most firmly adherent small portions, very dilute muriatic acid is used Muriatic acid might be employed from the first, were it not, that loss by too violent effervescence is very liable to take place; and that when manganese is present, chlorine is evolved, and the platinum vessel acted on. When the whole has been completely removed from the crucible, muriatic acid is added till a decided acid reaction is obtained, but cautiously, to avoid loss by too strong effervescence The capsule is then set to digest for some time on the warm sand-bath. The silica now appears as a light flocky sediment, but a portion of it, and in some cases even the whole, exists in a state of solution The decomposition is known to be completely effected, when on stirring with a glass rod, no fine gritty matter is felt in the bottom of the capsule Should the decomposition prove incomplete, the flocks of silica are floated off in the solution, and the undecomposed portion is washed clean by affusion Having dried the powder completely, it is mixed with a fresh portion of carbonate of potash, subjected a second time to ignition, and the fused mass is dissolved out and treated as before

The solution is now evaporated to perfect dryness; but the heat requires careful regulation towards the close, to avoid loss by spurting The dry mass is uniformly moistened with a few drops of strong muriatic acid,

* In place of the argand burner, I have more recently used, with great advantage, the ring burner mounted on the waterlute apparatus figured by Dr. Clark in the Transactions of the Chemical Society Its advantage, when used to supply gas to the wire-gauze gas-furnace, is, that a more complete and uniform mixture is effected, and the blue flame above the gauze is thereby much improved For igniting precipitates before weighing, and for most common purposes, the dome is unnecessary.

and left to stand in the cold for some time, after which it is treated with water, which dissolves every thing but the silica, and it is collected on a weighed filter, washed, dried, ignited and weighed.

The acid solution filtered from silica is analysed in the same way as the solution obtained by treating the impalpable matter of the soil with hot concentrated muriatic acid, page 151; only, from the use of carbonate of potash in the process, the alkalies cannot be directly determined.

METHOD OF ANALYSING THE RESIDUUM INSOLUBLE IN DILUTE MURIATIC ACID, BY HYDROFLUORIC ACID

As it is a defect in the method of analysing silicates by fusion with carbonate of potash, that the alkalies cannot be estimated, it is necessary to shew how this may be effected, should the operator think it necessary to do so In that case, however, it would be advisable, after treating the ignited impalpable matter with dilute muriatic acid, page 149, and analysing the solution thereby obtained, to dispense with the process of treating the residue with hot concentrated muriatic acid, because, with the exception of silica, all the substances contained in it can be accurately estimated by the process about to be described

The impalpable residue, filtered from the dilute muriatic acid solution, is, after being weighed, placed in a pretty large platinum capsule, set near a ventilator or other contrivance for carrying off fumes, and recently prepared fuming hydro-fluoric acid is poured upon it The mixture is well stirred with a platinum spatula, and sulphuric acid is added An evolution of gaseous fluoride of silicon and hydro-fluoric acid takes place, and when the heat is raised, excess of sulphuric acid escapes To ensure the escape of the latter, the heat, towards the close of the process, is gradually raised till the vessel is heated to incipient redness The whole is then allowed to cool, and to replace the acid that has been driven off from some of the bases, the mass is uniformly moistened with muriatic acid, and allowed to stand in the cold for half an hour The mass is now treated with water, and the whole is warmed The small quantity of silica present is separated by filtration, and the filter is washed free from acid

Progress of the Analysis —The filtered solution is analysed nearly in the same manner as has been already pointed out Free acid is neutralised by ammonia, a slight excess of which throws down peroxide of iron and alumina, together with small quantities of manganese and magnesia All these are treated as described, pages 152-3.

Lime is next thrown down by oxalate of ammonia and manganese by hydro-sulphate of ammonia

Separation and Estimation of Magnesia and the Alkalies —The solution, filtered from sulphuret of manganese, after being acidulated with muriatic acid, boiled and filtered, is evaporated to dryness and cautiously ignited. The residuum, which consists of magnesian and alkaline sulphates, must be converted into chlorides, both for the purpose of separating magnesia by the method already described, and for the separation of the alkalies from each other.

For this purpose, the sulphates are dissolved, the solution is warmed, and acetate of baryta is cautiously added till all the sulphuric acid is precipitated, but excess must be avoided. After the precipitate has subsided, it is collected on a filter and washed clean. To the filtered solution muriatic acid is added, and it is slowly evaporated to dryness, heated to incipient redness, and weighed; after which, the separation and estimation of magnesia and the alkalies is proceeded with as described, page 146.

Since by this process the silica cannot be estimated, it is necessary to determine its quantity by fusing a separate portion of dry impalpable matter with carbonate of soda.

ON THE ORGANIC CONSTITUENTS OF SOILS.

So little has yet been done in the way of investigating the composition, properties, and functions of the organic constituents of soils, that it is impossible to give precise directions regarding their separation and estimation; and hence, in the previous pages of this appendix, the general method has been recommended, of ascertaining the amount of finely divided organic matter, by igniting a weighed portion of it, after having been as completely dried as can be done without decomposition. The loss of weight, after ignition, expresses the amount of organic matter, together with a very small portion of water, that could not be driven off by the previous drying; but this chiefly in the case of clayey soils.

It is obvious, however, that but little actual information is obtained by this mode of proceeding; and that it is highly desirable to know more about the condition of the organic matter, its state and manner of decomposition, the ways in which it ministers to plants, the substances that retard or accelerate its decay, its relation to moisture, texture, and many other particulars. Full information on these important points cannot be obtained, till a far greater amount of study and research has been bestowed on the subject.

Of recent researches, the most elaborate is that of Mulder: and the following observations on the nature and composition of these bodies, is condensed from Berzelius's "*Rapport Annuel sur les Progrès de la Chimie*," 1841.

The ulmin and ulmic acid, humin and humic acid of soils, Mulder shews to be analogous to bodies bearing the same names, and capable of being readily produced by acting on sugar with diluted acids, and by some other methods. The bodies so produced are dark in colour, for the most part electro-negatives, combine with the alkalies, and produce black or dark-brown salts, uncrystallisable, and very soluble. Several of them have so feeble a capacity for saturation, compared with the quantity of oxygen which they contain, that the acid possesses ten, twelve, or fourteen times as much oxygen as the base; hence, they are believed to be composed of a single oxide of a compound radical.

The following table represents the composition of some of the bodies formed by the catalytic action of dilute sulphuric acid on sugar, and most analogous to the organic bodies found in soils.

Ulmin, $C_{40}\ H_{16}\ O_{14}$.
Ulmic Acid, $C_{40}\ H_{14}\ O_{12}$.
Humin, $C_{40}\ H_{15}\ O_{15}$.
Humic Acid, $C_{40}\ H_{12}\ O_{12}$.

When sugar is digested with dilute sulphuric acid at the temperature of 156° F., the colour of the liquor becomes brown, and flakes are gradually deposited, which consist of ulmin and ulmic acid. They are separated by treatment with solution of caustic potash, which takes up the ulmic acid and leaves the ulmin. The ulmic acid is obtained in the form of gelatinous clots, by supersaturating the potash solution with muriatic acid. When separated by filtration, washed, and dried at 383° F., the ulmic acid is anhydrous, but at a higher temperature it suffers decomposition.

Humin and humic acid are prepared by a similar process, but at a higher temperature, and free admission of air is necessary; for Mulder shews that it is ulmin and ulmic acid that are the primary products, and that they are converted by the air into humin and humic acid. The humin and humic acid are separated by the same means as ulmin and ulmic acid.

Both ulmic and humic acids can combine with ammonia, forming salts composed of single equivalents of acid and base; and capable of being dried at 284° F.

From the study of these and other bodies, Mulder proceeded to the examination of peats, mouldered woods, and soils. Peat, that has been formed with but partial admission of air, contains ulmin and ulmic acid; and black peat, formed with free access of air, contains humin and humic acid.

A brown peat from la Frise, after the removal of resinous matter by alcohol, was treated with solution of carbonate of soda, and yielded a brown solution, which, on being supersaturated with muriatic acid, gave a flocky precipitate of ulmic acid, in some respects different from the artificial ulmic acid; for it contained two more atoms of water, being represented by the formula $C_{40}\ H_{16}\ O_{14}$, and is therefore isomeric with ulmin; moreover, it could not resist a higher temperature than 284° F., without decomposition; being 99° less than that to which the ulmic acid from sugar could be safely subjected.

The ulmin of the peat remained of course with the unaltered vegetable debris from which the carbonate of soda solution was filtered.

By similar treatment of a black peat from the lake of Harlem, Mulder obtained humic acid, possessing the external appearance of that obtained from sugar. It, however, contained ammonia, and on supersaturating the carbonate of soda solution with muriatic acid, fell in combination with that base. The ammoniacal salt, which could safely be dried at 284° F., gave, on analysis, numbers which correspond to the formula $NH_4\ O + C_{40}\ H_{12}\ O_{12} + 3\ HO$. The three atoms of water, however, Berzelius considers as belonging essentially to the acid, which, therefore, would be represented by the formula $C_{40}\ H_{15}\ O_{15}$, and would be isomeric with artificial humin.

In examining the organic constituents of the soils of cultivated fields and gardens, Mulder had to deal with less pure and uniform products. After treating them with alcohol and water to separate crenic and apocrenic acids, he acted on them by means of solution of carbonate of soda, and on saturating the alkaline solution as before, he obtained, in every case, precipitates of ammoniacal salts. These salts were found capable of being dried unaltered at 284° F., and on being analysed, gave results corresponding to the following formulæ:—

From the soil of an orchard, . . .	$NH_4\ O + C_{40}\ H_{20}\ O_{17}$.
The same, after being dissolved in ammonia and evaporated to dryness, ...	$2\ NH_4\ O + C_{40}\ H_{12}\ O_{14}$.
From the soil of a kitchen garden, . .	$NH_4\ O + C_{40}\ H_{15}\ O_{15}$.
.....Meadow, (at 383° F.) .	$2\ NH_4\ O + C_{40}\ H_{14}\ O_{14}$.
.....Plantation of oaks, . .	$NH_4\ O + C_{40}\ H_{17}\ O_{17}$.

On these, Berzelius remarks:—"These analyses prove that fertile soils contain combinations of ammonia with acids, which correspond to those of humic and ulmic acids, in all containing 40 atoms of carbon; but the hydrogen and oxygen are variable, whether in the proportions requisite to

form water, or in the oxygen or hydrogen being in excess. The number of thse variations, is, perhaps, not great; that however is not yet known, and it will appear to us much more considerable than it really is, so long as our information does not permit of our arriving at more precise results; for in all probability, the soil contains all these varieties more or less mixed, which give, by analysis, an apparently equal result as to the 40 atoms of carbon, but which present continual differences between the hydrogen and oxygen, according to the proportion of the acids which concur to form the mixture of these ammoniacal compounds."

From the foregoing statements it is easy to see that great difficulties attend the separation and estimation of the organic matters of soils. Perhaps the safest way of proceeding, is to treat a known weight of the impalpable matter of the soil with alcohol, to remove resinous matter; and next to digest it in successive portions of solution of carbonate of soda, as long as any thing is taken up, which may be judged of by the colour. The solution, having been freed from the residuum by filtration, is supersaturated with muriatic acid, and the humic and ulmic acids are collected on a weighed filter, and washed with water rendered acidulous by muriatic acid; but the washing cannot be long continued, as the acids are to some extent soluble. The precipitate is now dried at 284° F., till it ceases to lose weight. It is obvious that the precipitate may be a mixture of humic and ulmic acids, incapable of accurate separation; and farther, it is almost sure to contain ammonia. If it is merely desired to ascertain the presence of ammonia, it may be done by heating a portion of the dried precipitate in a tube with caustic potash or quick lime, when the smell of ammonia will be perceived; or the ammonia may be detected by a grey litmus-paper held in the mouth of the tube. If it is desired to subject the mixture to a more rigorous examination, the only satisfactory method is that of ultimate analysis.

The humin and ulmin of course remain with the unaltered vegetable debris in the residuum from which the carbonate of soda solution was filtered. Sprengel recommends the humin (coal of humus) to be separated from the vegetable debris by digestion in a solution of caustic potash, and precipitated by muriatic acid. The accuracy of this method, however, is more than questionable, if the humin of soils is at all analogous to that described by Mulder as obtained from sugar. But if the operator has recourse to this process, the method by which the humic acid (?) was obtained, ought to be specified, that it may be distinguished from the humic acid obtained by the former process.

The great difficulty attendant on the whole question of the organic matters of soils, is, that we can never be sure that the substances separated existed as such in the soils. The method by which humic acid is separated by digestion in solution of carbonate of soda is, in this respect, less objectionable than digestion in caustic potash.

The chief nutritive function of the strictly organic matter of soils appears to be the supply of carbonic acid to the roots of plants growing in them; but as organic matters decay, the supply of carbonic acid gradually diminishes, and hence the importance of ascertaining the exact state and capabilities in this respect of the organic matters. In the present state of our knowledge, the estimation of the organic matter in mass, and of the ulmic and humic acids extracted or produced by digestion in solution of carbonate of soda, is, perhaps, all that can be readily effected, or with much certainty depended on. It is a pity that this and similar points of vital importance to agriculture, are not taken up at the instance of some

of our great Societies for the advancement of agriculture; for they are so difficult, and so exclusively agricultural in their bearing, that a speedy solution of them can scarcely be expected from chemists, whose labours are often more directed to the development of the general doctrines of the science, than to the elucidation of points connected with its application to a particular art.

STATEMENT OF RESULTS.

When the various analytical processes which the operator has found necessary are concluded, the results are collected, and a tabular statement made up. Or, as it is always more satisfactory, three such statements may be made; one of the mechanical examination, one of the soluble saline matter, and one of the insoluble finely-divided portion. The second and third of these might be simple statements of the weights of the different substances found; but it is more common to state them in the way in which they were combined, or are believed to have existed in the soil. After what has been incidentally mentioned in the course of the foregoing directions regarding the state of combination of the various constituents of soils, it is necessary to make but a few remarks on the subject for the sake of beginners.

In stating the results of the analysis of the portion soluble in water, assuming that the solution was neutral, and that sulphuric acid and chlorine, together with the bases, lime, potash, and soda were found, the quantity of lime required to combine with the quantity of sulphuric acid found, would be ascertained by calculation, and if the two results coincided, the sulphuric acid and lime would be considered to have existed in the soil as gypsum. If there were more sulphuric acid, than with the lime found, would form sulphate, the rest of it would be similarly assigned to potash, and then to soda. In like manner the chlorine would be assigned to sodium, and the balance to potassium.

In the insoluble portion, the lime and magnesia exist as silicates, carbonates, phosphates, or in combination with organic acids. In the first three cases, the bases are obtained by treatment with dilute muriatic acid, and are assigned after the estimation of all the substances present. Oxides of iron and manganese may occur, especially in subsoils, as carbonates, but in soils they are much more frequently found as hydrated peroxides, or associated with organic matter. Alumina sometimes occurs as hydrate, and united with organic acids, but generally as silicate.

With respect to silicates, nothing is ever attempted beyond the statement of the acid and bases separately, distinguishing the latter, however, from the same bases that have existed in the soil in combination with other acids.

As the methods of separating and estimating the different substances present in a soil are by no means perfect, few of the so-called insoluble precipitates being absolutely so, it is obvious, that some loss must occur from this cause, not to mention others; and hence, on collecting all the different estimates, their sum must fall a little short of the original weight of the portion of soil operated on. Beginners, however, are more likely to obtain an increase of weight, from not being sufficiently schooled into the necessity of thoroughly washing the various precipitates.

In place of a minute analysis and estimation of all the constituents of a soil, it is more frequently required to ascertain the presence or absence of some particular constituent; and if present, to estimate it. This has frequently to be done with lime, magnesia, phosphoric acid, and alkalies.

The methods employed are essentially the same as those already described, and a little practice will enable the operator so to modify them as to have no unnecessary trouble.

It may not be out of place here to mention, that in examining a soil with the view of ascertaining whether it contains enough of any particular body for the wants of the crop to be cultivated, that too much attention cannot be given to the state of division in which the substance exists. For analysis may shew a sufficient quantity of the body in question for a series of crops of the kind wished to be cultivated, and still, practically, the soil may be deficient in the substance. Thus, it is quite possible, that a soil containing no carbonate of lime, might be dressed with a coarse calcareous gravel to such an extent, as to shew in the analysis of the whole soil, an average quantity of calcareous matter; and yet for the requirements of the crops, be still deficient in lime. In this case, however, were the impalpable portion, which is most uniformly diffused through the whole mass, and certainly presents the greatest surface for the roots to imbibe from, were this impalpable matter separated as directed in the mechanical examination, and by itself submitted to analysis, the deficiency in calcareous matter could not fail to be discovered. Indeed, the method of analysing the soil in mass is objectionable, and often leads to unsatisfactory results.

Again, a constituent may be present in fine division of parts, well diffused through the whole mass of soil, and in quantity amply sufficient for the use of the crops; and yet, unless the analysis is a very accurate one, and made on a considerable quantity of the soil, even a good manipulist may fail in estimating it; and so pronounce it absent, or present in insufficient quantity.

This would have been the proper place to collect together tables of analyses of soils whose history, texture, and capabilities are known, and to have deducted from them such practical conclusions as the data would afford. In the present state of our information, however, this would be unsafe; for, comparatively few foreign, and almost no British analyses of acknowledged value have yet been published. Most of the good analyses before the public, it must be regretted, are extremely deficient in the mechanical or textural part, without a knowledge of which, few practical conclusions can with safety be drawn. An additional defect in most of the published analyses, is the want of an accurate account of the ascertained capabilities of the soil; and perhaps a still more effectual bar to the conclusions referred to, is the want of precise information regarding the inorganic constituents of plants.

It is satisfactory, however, to find that many distinguished agriculturists are now aware of the importance of accurate information on these points; and it is to be hoped, that ere long, these deficiencies will be supplied.

LECTURE V.

ON THE NATURE AND CONSTITUTION OF THE ATMOSPHERE; AND ITS INFLUENCE ON VEGETABLES—OF THE GERMINATION OF SEEDS—OF THE FUNCTIONS OF PLANTS IN THEIR DIFFERENT STAGES OF GROWTH—WITH A GENERAL VIEW OF THE PROGRESS OF VEGETATION.

THE constitution of the atmosphere has been already generally referred to in the preceding Lectures. Water, carbonic acid gas, oxygen, and azote, have been mentioned as the principal substances composing it; but more minute enquiries respecting their nature and agencies are necessary to afford correct views of the uses of the atmosphere in vegetation.

On these enquiries I now propose to enter; the pursuit of them, I hope, will offer some objects of practical use in farming; and present some philosophical illustrations of the manner in which plants are nourished; their organs unfolded, and their functions developed.

If some of the salt called muriate of lime that has been just heated red be exposed to the air, even in the driest and coldest weather, it will increase in weight and become moist; and in a certain time will be converted into a fluid. If put into a retort and heated, it will yield pure water; will gradually recover its pristine state; and, if heated red, its former weight: so that it is evident, that the water united to it was derived from the air. And that it existed in the air in an invisible and elastic form, is proved by the circumstance, that if a given quantity of air be exposed to the salt, its volume and weight will diminish, provided the experiment be correctly made.

The quantity of water which exists in air, as vapour, varies with the temperature. In proportion as the weather is hotter, the quantity is greater. At 50° of Fahrenheit, air contains about $\frac{1}{50}$ of its volume of vapour; and as the specific gravity of vapour is to that of air nearly as 10 to 15, this is about $\frac{1}{75}$ of its weight.*

At 100°, supposing that there is a free communication with water, it contains about $\frac{1}{14}$ part in volume, or $\frac{1}{21}$ in weight. It is the condensation of vapour by diminution of the temperature of the atmosphere, which is probably the principal cause of the formation of clouds, and of the deposition of dew, mist, snow, or hail.†

* Air at 50° F., with all the vapour it can take up, contains about $\frac{1}{81}$ of its volume, which corresponds very nearly with $\frac{1}{130}$th of its weight.

† It is sufficient for the precipitation of moisture, that two portions of air, of different temperatures, but each containing the full complement of vapour due to its temperature, be mixed together. The temperature speedily arrives at the

The power of different substances to absorb aqueous vapour from the atmosphere by cohesive attraction was discussed in the last Lecture. The leaves of living plants appear to act upon the vapour likewise in its elastic form, and to absorb it. Some vegetables increase in weight from this cause, when suspended in the atmosphere and unconnected with the soil; such are the house-leek, and different species of the aloe.* In very intense heats, and when the soil is dry, the life of plants seems to be preserved by the absorbent power of their leaves; and it is a beautiful circumstance in the economy of nature, that aqueous vapour is most abundant in the atmosphere when it is most needed for the purposes of life; and that when other sources of its supply are cut off, this is most copious.

The compound nature of water has been referred to. It may be proper to mention the experimental proofs of its decomposition into, and composition from, oxygen and hydrogen.

If the metal called potassium be exposed in a glass tube to a small quantity of water, it will act upon it with great violence; elastic fluid will be disengaged, which will be found to be hydrogen; and the same effects will be produced upon the potassium, as if it had absorbed a small quantity of oxygen; and the hydrogen disengaged, and the oxygen added to the potassium are in weight as 2 to 15; and if two in volume of hydrogen, and one in volume of oxygen, which have the weights of 2 and 15, be introduced into a close vessel, and an electrical spark passed through them, they will inflame and condense into 17 parts of pure water.†

It is evident from the statements given in the third Lecture, that water forms by far the greatest part of the sap of plants; and that this substance, or its elements, enters largely into the constitution of their organs and solid productions.

Water is absolutely necessary to the economy of vegetation in its elastic and fluid state; and it is not devoid of use even in its solid form. Snow and ice are bad conductors of heat; and when the ground is covered with snow, or the surface of the soil or of water is frozen, the roots or bulbs of the plants beneath are protected by the congealed water from the influence of the atmosphere, the temperature of which in northern winters is usually very much below the freezing point; and this water becomes the first nourishment of the plant in early spring. The expansion of water during its congelation, at which time its volume increases $\frac{1}{12}$, and its contraction of bulk during a thaw, tend to pulverise the soil; to separate

mean, but the mean temperature cannot support the mean quantity of vapour, a portion of it is therefore precipitated in the form of cloud, rain, or snow, according to circumstances. Hail seems always to be produced by the falling of rain from a warmer, through a colder stratum of air. Dew is formed only on the surface of the earth; and it arises from the cooling of bodies by radiation; hence, it occurs on the coldest portions of the best radiators, such as grass, &c., and only on clear nights, as then only can the temperature fall considerably. It is most abundant in tropical countries, as there the quantity of vapour in the air is greatest; and in our climate most dew occurs in autumn and spring, there being at these seasons the greatest difference between the temperature of the day and night.

* Mr Macnab gives an interesting account of two fig trees (*F. Australis*) that were kept for many years in the Edinburgh Botanical Garden, suspended in air. They retained their vitality and annually put forth leaves.

† One equivalent of water 9, consists of one equivalent of oxygen 8, and one of hydrogen 1.

its parts from each other, and to make it more permeable to the influence of the air.*

If a solution of lime in water be exposed to the air, a pellicle will speedily form upon it, and a solid matter will gradually fall to the bottom of the water, and in a certain time the water will become tasteless; this is owing to the combination of the lime, which was dissolved in the water, with carbonic acid gas which existed in the atmosphere, as may be proved by collecting the film and the solid matter, and igniting them strongly in a little tube of platina or iron; they will give off carbonic acid gas, and will become quick lime, which added to the same water, will again bring it to the state of lime water.

The quantity of carbonic acid gas in the atmosphere is very small. It is not easy to determine it with precision, and it must differ in different situations; but where there is a free circulation of air, it is probably never more than $\frac{1}{500}$, nor less than $\frac{1}{800}$ of the volume of air.† Carbonic acid

* The influence of frost on stiff soils is twofold. 1st, It promotes disintegration and decomposition of the mineral constituents, by freezing in their interstices. In consequence of the great expansion that thus takes place, the parts of the soil are much more completely separated than could be done by the most efficient system of ordinary tillage. 2d, When the ice melts, the soil is left in an open porous condition, freely admitting air and moisture, and consequently, deriving from them, somewhat of the advantages at all times derived by more open soils. It appears, therefore, to be always advantageous to have stiff clays ploughed in autumn, to be mellowed by the frost: and this has long been regarded as the best practice, apart from theoretical considerations.

The action of frost on soils of looser texture, especially those that have been long in cultivation, and contain a considerable quantity of organic matter, deserves attention; particularly as equal benefit is not derived from it. When severe frost follows rain, such soils, especially if the subsoils are retentive, become greatly expanded by the freezing of the water contained in them. During the continuance of the frost the surface is hard and resonant when trod upon. When the ice melts, and the water disappears, the earth still retains its increased bulk, is quite porous and honey-combed, and pits deeply under the horses feet. Too free admission of air then takes place, and the plants which the frost had torn from their roots or positions, are exposed to the air, shrivel and die. Thus it is that wheat, and very frequently red clover are *thrown out* as it is termed.

Various plans are resorted to, to counteract the evil, such as rolling with a heavy compressing roller; ploughing when the soil is wet, to secure a clod or furrow of as great density as can be got; admixture of clay; deep ploughing; and, when the subsoil is clay or pan, thorough-draining and subsoiling: and all these methods have proved effectual when applied to the soils whose circumstances they are severally suitable to. The failure of clover, so generally attributed to want of gypsum and calcareous matter, is far more frequently thus produced; and many instances could be pointed out, where, by some of the above means it has been completely restored, after gypsum had failed to do so.

† Various estimates have been made of the mean quantity of carbonic acid in the air. The following table embraces the principal ones.

Name of Experimenters.	Places.	Carbonic Acid.	In parts of Air.
Thenard,	Paris,	1	2500
Saussure,	Switzerland,	1	2410
Verver,	Groningen,	1	2381
Boussingault,	Paris,	1	2519

The mean of the four is 1 in 2454, but it is obvious, that for all ordinary calculations Thenard's estimate, identical as it almost is with the last, and perhaps best estimate, that of Boussingault, may be assumed, namely, 1 in 2500.

gas is nearly $\frac{1}{3}$ heavier than the other elastic parts of the atmosphere in their mixed state: hence, at first view, it might be supposed that it would be most abundant in the lower regions of the atmosphere: but unless it has been immediately produced at the surface of the earth in some chemical process, this does not seem to be the case: elastic fluids of different specific gravities have a tendency to equable mixture by a species of attraction,* and the different parts of the atmosphere are constantly agitated and blended together by winds or other causes. De Saussure found lime water precipitated on Mount Blanc, the highest point of land in Europe; and carbonic acid gas has been always found, apparently in due proportion, in the air brought down from great heights in the atmosphere by aërostatic adventurers.†

The experimental proofs of the composition of carbonic acid gas are very simple. If 13 grains of well burnt charcoal be inflamed by a burning glass in 100 cubical inches of oxygen gas the charcoal will entirely disappear; and provided the experiment be correctly made, all the oxygen except a few cubical inches, will be found converted into carbonic acid; and what is very remarkable, the volume of the gas is not changed. On this last circumstance it is easy to found a correct estimation of the quantity of pure charcoal and oxygen in carbonic acid gas: the weight of 100 cubical inches of carbonic acid gas is to that of 100 cubical inches of oxygen gas, as 47 to 34: so that 47 parts in weight of carbonic acid gas,

Boussingault's trials were made daily for nine months. The monthly averages vary from 1 in 2632 to 1 in 2325. The maximum, 1 in 1493, occurred on the 9th September, and the minimum, 1 in 4545, on the 10th December. Of the observed monthly means, January gave the lowest, and May and July, which gave the same result, the highest. Boussingault's mean result above stated is of course the mean of all the daily observations.

Dumas and Boussingault have recently determined with much accuracy the ratio of oxygen and nitrogen in the air. They consider their research as rendering it probable that the air is a uniform mixture at all times in all latitudes, and at all heights, of 2301 parts of oxygen, and 7699 of nitrogen by weight; or of 20·81 of oxygen and 79·19 of nitrogen by volume.

The following statement in round numbers by Dr. Clark, conveys perhaps as simple an idea of the composition of the atmosphere as can be given.

1900	Volumes of	Nitrogen.
500	...	Oxygen.
1	..	Carbonic Acid.

* The hypothesis of independent equilibrium originated with Dalton, and has been confirmed and extended by Professor Graham. When two vessels containing different gases communicate with one another, diffusion takes place till each of the gases pervades the whole space to which it has access, independently of the presence of the other. The diffusiveness of any gas is represented by the reciprocal of the square root of its density. The density being known its diffusiveness may be calculated; or if it be a gas whose diffusiveness can be accurately determined by experiment, its density may be calculated. There is a very striking analogy between the diffusion of gases through porous media, and the exosmose and endosmose of liquids through membraneous tissues mentioned in a former note.

† By moisture in the air, and by water on the surface of the earth, as well as by the influence of light on plants, this gas is removed from the air. Accordingly, over the sea and lakes, it is found in smaller quantity than over the land, after rain than during dry weather, in winter than in summer, and near the earth than at great elevations.

must be composed of 34 parts of oxygen and 13 of charcoal, which correspond with the numbers given in the second Lecture.*

Carbonic acid is easily decomposed by heating potassium in it; the metal combines with the oxygen, and the charcoal is deposited in the form of a black powder.

The principal consumption of the carbonic acid in the atmosphere, seems to be in affording nourishment to plants; and some of them appear to be supplied with carbon chiefly from this source.†

Carbonic acid gas is formed during fermentation, combustion, putrefaction, respiration, and a number of operations taking place upon the surface of the earth; and there is no other process known in nature by which it can be destroyed but by vegetation.‡

After a given portion of air has been deprived of aqueous vapour and carbonic acid gas, it appears little altered in its properties; it supports combustion and animal life. There are many modes of separating its principal constituents, oxygen and azote, from each other. A simple one is by burning phosphorus in a confined volume of air: this absorbs the oxygen and leaves the azote: and 100 parts in volume of air, in which phosphorus has been burnt, yield 79 parts of azote; and by mixing this azote with 21 parts of fresh oxygen gas artificially procured, a substance having the original characters of air is produced. To procure pure oxygen from air, quicksilver may be kept heated in it, at about 600°, till it

* 100 cubic inches of carbonic acid gas weigh 47·262 grains, and its density is 1·524.

† Plants obtain supplies of carbonic acid from the atmosphere in two ways. 1st, By direct absorption through the leaves. This occurs in all plants, and in a very remarkable degree in those whose roots bear but small proportion to their stem and leaves. 2d, They obtain carbonic acid dissolved in water, by absorption through the roots. 100 cubic inches of water, at the standard temperature and pressure, can dissolve 106 cubic inches of carbonic acid gas, and as this gas is a constituent of the atmosphere, rain and spring water must always contain more or less of it.

But the carbonic acid supplied in solution to the roots of plants is not solely derived from the air, for this gas is a constant and abundant product of the decay of humus and organic matter in the soil. Herbaceous plants, such as form the staple of field culture, seem in their young state, to be greatly dependent on a supply of carbonic acid from the soil, and to thrive well only in soils where there is a large supply of carbonic acid from decay; but when the leaves and green parts are fully developed, they draw largely on the carbonic acid of the air.

‡ While the proposition in the text is admitted, it should be borne in mind, that all the carbonic acid taken up and appropriated by plants, is not restored again to the air; because, it is only in warm climates that complete decomposition of organic matter takes place. It has been shewn that in high latitudes, and especially where there is a humid climate, that decomposition proceeds only to a certain extent; and that a great deal of vegetable matter remains locked up in the state of peat and mould. The extensive deposits of coal and lignite attest the existence of a state of things somewhat similar in the earlier periods of the earth's history. But this conclusion will suggest the question: Is the carbonic acid of the air decreasing—are the living plants sufficiently numerous to decompose all that is produced by decay of organic matter, by the respiration of animals and the other sources of its production? To this it may be replied, that there is no direct evidence of its diminution, and that its fixation in peat may be an arranged counterpoise to its production from volcanoes, and generally from the interior of the earth.

becomes a red powder; this powder, when ignited, will be restored to the state of quicksilver by giving off oxygen.

Oxygen is necessary to some functions of vegetables; but its great importance in nature is in its relation to the economy of animals. It is absolutely necessary to their life. Atmospheric air taken into the lungs of animals, or passed in solution in water through the gills of fishes, loses oxygen; and for the oxygen lost, about an equal volume of carbonic acid appears.

The effects of azote in vegetation are not distinctly known. As it is found in some of the products of vegetation, it may be absorbed by certain plants from the atmosphere.* It prevents the action of oxygen from being too energetic, and serves as a medium in which the more essential parts of the air act; nor is this circumstance unconformable to the analogy of nature; for the elements most abundant on the solid surface of the globe, are not those which are the most essential to the existence of the living beings belonging to it.

The action of the atmosphere on plants differs at different periods of their growth, and varies with the various stages of the development and decay of their organs; some general idea of its influence may have been gained from circumstances already mentioned: I shall now refer to it more particularly, and endeavour to connect it with a general view of the progress of vegetation.

If a healthy seed be moistened and exposed to air at a temperature not below 45°, it soon germinates; it shoots forth a plume which rises upwards, and a radicle which descends.

If the air be confined, it is found that in the process of germination the oxygen, or a part of it is absorbed. The azote remains unaltered; no carbonic acid is taken away from the air, on the contrary some is added.

Seeds are incapable of germinating, except when oxygen is present. In the exhausted receiver of the air-pump, in pure azote, in pure carbonic acid, when moistened they swell, but do not vegetate; and if kept in these gases, lose their living powers, and undergo putrefaction.

If a seed be examined before germination, it will be found more or less insipid, at least not sweet; but after germination it is always sweet. Its coagulated mucilage, or starch, is converted into sugar in the process; a substance difficult of solution is changed into one easily soluble; and the sugar carried through the cells or vessels of the cotyledons, is the nourishment of the infant plant. It is easy to understand the nature of the change, by referring to the facts mentioned in the third Lecture; and the production of carbonic acid renders probable the idea, that the principal chemical difference between sugar and mucilage depends upon a slight difference in the proportions of their carbon.†

* It does not appear that plants derive any part of their nitrogen from this gas as it exists in an uncombined state in the atmosphere; for few substances are more indisposed to combination. Liebig has proved that plants derive their nitrogen from ammonia, a substance always present in the air in greater or less quantity, and a constant product of the decay of almost all organic bodies.

† Some idea of the nature of the changes that take place in the starch of a seed, during germination, may be inferred from the composition of these substances. Starch, according to the best analyses, consists of C_{12} H_{10} O_{10}. Now starch is converted into dextrine, a substance possessing most of the properties of gum, and next into sugar. The composition of dextrine is identical with that of starch, and sugar differs only in containing a greater proportion of the

The absorption of oxygen by the seed in germination, has been compared to its absorption in producing the evolution of fœtal life in the egg; but this analogy is only remote. All animals, from the most to the least perfect classes, require a supply of oxygen.* From the moment the heart begins to pulsate till it ceases to beat, the aeration of the blood is constant, and the function of respiration invariable; carbonic acid is given off in the process, but the chemical change produced in the blood is unknown; nor is there any reason to suppose the formation of any substance similar to sugar. In the production of a plant from a seed, some reservoir of nourishment is needed before the root can supply sap; and this reservoir is the cotyledon in which it is stored up in an insoluble form, and protected if necessary during the winter, and rendered soluble by agents which are constantly present on the surface. The change of starch into sugar, connected with the absorption of oxygen, may be rather compared to a process of fermentation than to that of respiration; it is a change

elements of water. Crystallised grape sugar consists of C_{12} H_{14} O_{14}, or dried at 130° F., of C_{12} H_{12} O_{12}; and germination can take place only with access of air and moisture, and heat is known to be produced during the process, and carbonic acid evolved. It is grape sugar that is always formed in germinating seeds. Dextrine differs in many points from starch; it is soluble in water, and, of its two varieties, the one gives a purple colour with iodine, the other gives no change.

Recent researches have brought to light other interesting facts regarding germination. When it is wished to obtain alcohol or any fermented liquor from barley, the grain is steeped in water, and laid in heaps at a certain temperature till germination proceeds as far as is required. The vitality of the young plant is destroyed by shoveling and kiln-drying, after which, the malt is ground or bruised. The malt thus prepared contains a substance, soluble in water, termed *diastase*, formed from gluten, and possessed of the power of converting starch into dextrine, and finally into grape sugar. *Wort* consists of a decoction of diastase and of the starch undergoing the change into sugar. The quantity of diastase contained in good malt is capable of converting a much greater quantity of starch into dextrine than is present in the barley; hence, starch, potatoes, raw grain, &c., are advantageously mixed with the malt. When the digestion of the mixture is continued, the diastase disappears, and the dextrine is converted into grape sugar.

In the natural germination of seeds in the ground, diastase is in like manner produced, and its presence can be traced till all the starch of the seed is rendered soluble and available for nourishing the young plant; in other words, till the insoluble starch is converted into soluble sugar. Diastase has been found in wheat, barley, rye, &c., after germination had commenced, and also in the potato and similar tubers at the base of the young shoots. The conversion of the starch into sugar is considered by Liebig to be caused by a transformation that goes on in the diastase; and accordingly, by the time that the young plant is so far developed as to be able to draw nourishment for itself from the soil and the air, the diastase has completely disappeared, having, no doubt, contributed in its turn to the formation of the azotised parts of the plant.

* The impregnated eggs of insects, and even fishes, do not produce young ones, unless they are supplied with air, that is, unless the fœtus can respire. I have found that the eggs of moths did not produce larvæ when confined in pure carbonic acid; and when they were exposed in common air, the oxygen partly disappeared, and carbonic acid was formed. The fish in the egg or spawn, gains its oxygen from the air dissolved in water; and those fishes that spawn in spring and summer in still water, such as the pike, carp, perch, and bream, deposit their eggs upon subaquatic vegetables, the leaves of which, in performing their healthy functions, supply oxygen to the water. The fish that spawn in winter, such as

effected upon unorganized matter, and can be artificially imitated;* and in most of the chemical changes that occur when vegetable compounds are exposed to air, oxygen is absorbed, and carbonic acid formed or evolved.

It is evident, that in all cases of tillage, the seeds should be sown so as to be fully exposed to the influence of the air. And one cause of the unproductiveness of cold clayey adhesive soils is, that the seed is coated with matter impermeable to air.

In sandy soils the earth is always sufficiently penetrable by the atmosphere; but in clayey soils there can scarcely be too great a mechanical division of parts in the process of tillage. Any seed not fully supplied with air, always produces a weak and diseased plant.

The process of malting, which has been already referred to, is merely a process in which germination is artificially produced; and in which the starch of the cotyledon is changed into sugar; which sugar is afterwards, by fermentation, converted into spirit.

It is very evident from the chemical principles of germination, that the process of malting should be carried on no farther than to produce the sprouting of the radicle, and should be checked as soon as this has made its distinct appearance. If it is pushed to such a degree as to occasion the perfect development of the radicle and the plume, a considerable quantity of saccharine matter will have been consumed in producing their expansion, and there will be less spirit formed in fermentation, or produced in distillation.

As this circumstance is of some importance, I made in October, 1806, an experiment relating to it. I ascertained by the action of alcohol, the relative proportions of saccharine matter in two equal quantities of the same barley; in one of which the germination had proceeded so far as to occasion protrusion of the radicle to nearly a quarter of an inch beyond the grain in most of the specimens, and in the other of which it had been checked before the radicle was a line in length; the quantity of sugar afforded by the last was to that in the first nearly as six to five.

The saccharine matter in the cotyledons at the time of their change into seed-leaves, renders them exceedingly liable to the attacks of insects: this principle is at once a nourishment of plants and animals, and the greatest ravages are committed upon crops in this first stage of their growth.

The turnip fly, an insect of the colyoptera genus, fixes itself upon the seed-leaves of the turnip at the time that they are beginning to perform their functions: and when the rough leaves of the plume are thrown forth, it is incapable of injuring the plant to any extent.

Several methods have been proposed for destroying the turnip fly, or for preventing it from injuring the crop. It has been proposed to sow radish-seed with the turnip-seed, on the idea that the insect is fonder of the seed-leaves of the radish than those of the turnip; it is said that this

the salmon and trout, seek spots where there is a constant supply of fresh water, as near the sources of streams as possible, and in the most rapid currents, where all stagnation is prevented, and where the water is saturated with air, to which it has been exposed during its deposition from clouds. It is the instinct leading these fish to seek a supply of air for their eggs which carries them from seas, or lakes, into the mountain country; which induces them to move against the stream, and to endeavour to overleap weirs, mill-dams, and cataracts.—D.

* Starch can be converted into grape sugar by digestion in water, by the catalytic action of dilute sulphuric acid, or, as already noticed, by diastase.

plan has not been successful, and that the fly feeds indiscriminately on both.

There are several chemical menstrua which render the process of germination much more rapid, when the seeds have been steeped in them. As in these cases the seed-leaves are quickly produced, and more speedily perform their functions, I proposed it as a subject of experiment to examine whether such menstrua might not be useful in raising the turnip more speedily to that state in which it would be secure from the fly; but the result proved that the practice was inadmissable; for seeds so treated, though they germinated much quicker, did not produce healthy plants, and often died soon after sprouting.

I steeped radish seeds in September 1807, for 12 hours, in a solution of chlorine, and similar seeds in very diluted nitric acid, in very diluted sulphuric acid, in weak solution of oxysulphate of iron, and some in common water. The seeds in solutions of chlorine and oxysulphate of iron, threw out the germ in two days: those in nitric acid in three days, in sulphuric acid in five, and those in water in seven days. But in the cases of premature germination, though the plume was very vigorous for a short time, yet it became at the end of a fortnight weak and sickly; and at that period less vigorous in its growth than the sprouts which had been naturally developed, so that there can be scarcely any useful application of these experiments.* Too rapid growth and premature decay seem invariably connected in organized structures; and it is only by following the slow operations of natural causes, that we are capable of making improvements.

There is a number of chemical substances which are very offensive and even deadly to insects, which do not injure, and some of which even assist vegetation. Several of these mixtures have been tried with various success; a mixture of sulphur and lime, which is very destructive to slugs, does not prevent the ravages of the fly on the young turnip crop. His Grace the Duke of Bedford, at my suggestion, was so good as to order the experiment to be tried on a considerable scale at Woburn farm: the mixture of lime and sulphur was strewed over one part of a field sown with turnips; nothing was applied to the other part, but both were attacked in nearly the same manner by the fly.

Mixtures of soot and quicklime, and urine and quicklime, will probably be more efficacious. The volatile alkali given off by these mixtures is offensive to insects; and they afford nourishment to the plant. Mr T. A. Knight† informs me, that he has tried the method by ammoniacal fumes

* In some parts of the country it has long been customary to facilitate the growth of potato sets by steeping them, for a short time previous to planting, in a weak solution of oxalic acid. By this treatment the sets are said to gain a fortnight, and the plants to be fully as healthy as others. The subject deserves examination.

† Mr Knight has been so good as to furnish me with the following note on this subject.—D.

"The experiment which I tried the year before last, and last year, to preserve turnips from the fly, has not been sufficiently often repeated to enable me to speak with any degree of decision; and last year all my turnips succeeded perfectly well. In consequence of your suggestion, when I had the pleasure to meet you some years ago at Holkham, that lime slaked with urine might possibly be found to kill, or drive off, the insects from a turnip crop, I tried that preparation in mixture with three parts of soot, which was put into a small barrel,

with success; but more extensive trials are necessary to establish its general efficacy. It may, however, be safely adopted, for if it should fail in destroying the fly, it will at least be an useful manure to the land.*

with gimblet holes round it, to permit a certain quantity of the composition, about four bushels to an acre, to pass out, and to fall into the drills with the turnip seeds. Whether it was by affording highly stimulating food to the plant, or giving some flavour which the flies did not like, I cannot tell; but in the year 1811, the adjoining rows were eaten away, and those to which the composition was applied, as above described, were scarcely at all touched. It is my intention in future to drill my crop in, first, with the composition on the top of the ridge; and then to sow at least a pound of seed, broad-cast, over the whole ground. The expense of this will be very trifling, not more than 2s. per acre; and the horse-hoe will instantly sweep away all the supernumeraries between the rows, should those escape the flies, to which however they will be chiefly attracted; because it will always be found that those insects prefer turnips growing in poor, to those in rich ground. One advantage seems to be the acceleration given to the growth of the plants, by the highly stimulative effects of the food they instantly receive as soon as their growth commences, and long before their radicles have reached the dung. The directions above given apply only to turnips sowed upon ridges, with the manure immediately under them; and I am quite certain, that in all soils turnips should be thus cultivated. The close vicinity of the manure, and the consequent short time required to carry the food into the leaf, and return the organizable matter to the roots, are, in my hypothesis, points of vast importance; and the results in practice are correspondent.

* After trial of innumerable substances and mixtures, practical men seem almost unanimously to have arrived at the conclusion, that little or nothing can be done in the way of cure when the turnip fly (*Altica nemorum*) has once established itself. As ammonia is obviously the active principle of the mixtures used by Knight, I made trial of a diluted solution of that substance in the summers of 1841 and 42, on a field much infested with the fly, but without success.

As the fly attacks only the seminal leaves of the plants, it seldom proves very destructive, unless when the braird is scanty, and the plants are sickly from protracted drought and cold weather. On the east coast of Scotland dry east-winds frequently prevail about the time of turnip sowing, and when this is the case, the growth of the plants is slow, and they continue long in a condition that courts the depredations of the fly. Slow growth from any other cause would doubtless produce the same effect.

The most efficient means of prevention are—1st, Liberal manuring, to promote rapid and luxuriant growth. For this purpose it is essential that the manure be not too much diffused through the ground, nor so deeply buried that the young plants cannot reach it. That both these evils are avoided in the drill system appears from a consideration of its nature, as well as from the uniform success that is known to attend its use. A vigorous braird is still further secured, by using, in addition to the ordinary dose of farm-yard manure, some of the more rapidly acting extraneous manures, such as guano, bone-dust, or dry bone dust with sulphuric acid. These substances are either hand-sown above the dung before covering in with the plough, or when economy is studied, they are dibbled, or put in by the dust-dropper after the covering in of the manure.—2d, Thick sowing, to secure abundance of plants, so that if a portion should be attacked, there may be others to supply the deficiency; the surplus is easily got quit of by the hoe. In addition to thick sowing in the drills, it is well to sow about a pound of seed per acre broad-cast over all, as the plants growing between the drills appear rather before the others, and being besides but feeble plants, are preferred by the fly to the rest. 3d, The destruction of all cruciferous weeds, such as the common charlock (*Sinapis arvensis*), the jointed-charlock (*Raphanus Raphanistrum,*) on which, as well as on the turnip plants, the fly-

After the roots and leaves of the infant plant are formed, the cells and tubes throughout its structure become filled with fluid, which is usually supplied from the soil, and the function of nourishment is performed by the action of its organs upon the external elements. The constituent parts of the air are subservient to this process; but, as it might be expected, they act differently under different circumstances.

When a growing plant, the roots of which are supplied with proper nourishment, is exposed in the presence of solar light to a given quantity of atmospherical air, containing its due proportion of carbonic acid, the carbonic acid after a certain time is destroyed, and a certain quantity of oxygen is found in its place. If new quantities of carbonic acid gas be supplied, the same result occurs; so that carbon is added to plants from the air by the process of vegetation in sunshine; and oxygen is added to the atmosphere.

This circumstance is proved by a number of experiments made by Drs. Priestly, Ingenhousz and Woodhouse, and M. T. de Saussure; many of which I have repeated with similar results. The absorption of carbonic acid gas, and the production of oxygen are performed by the leaf; and leaves recently separated from the tree effect the change, when confined in portions of air containing carbonic acid; and absorb carbonic acid and produce oxygen, even when immersed in water holding carbonic acid in solution.

The carbonic acid is probably absorbed by the fluids in the cells of the green or parenchymatous part of the leaf; and it is from this part that oxygen gas is produced during the presence of light. M. Sennebier found

feeds, and by which it is preserved in the ground during the other years of the rotation. Few weeds are so difficult to deal with as the two referred to; their seeds are extremely tenacious of life, a deeper ploughing than usual will often, in lands long infested with them, cover the whole surface of the ground, the seeds having lain dormant for many years. Some instances have come under my own observation, where the seeds of the Sinapis arvensis have vegetated freely after being buried for more than forty years. These weeds appear in greatest abundance among the white crop taken after lea, and in the land preparing for fallow crops. In the latter case, when the weather is favourable, two or more crops of weeds may be made to vegetate and be destroyed in a single season: in the former case they are more difficultly subdued; but a turn of the harrows, after the grain plants are in their second leaf, will destroy a great many, and hand weeding must do the rest. All the plants of Sinapis, however, that escape, ripen, and mostly sow their seeds before the white crop can be gathered in. In some seasons it happens that a considerable number of cruciferous weeds must be allowed to stand, and are cut and housed along with the grain, and unless their seeds are carefully separated from the dressed grain by a seed-seive, they may be again sown with the seed-corn. The pod of the Raphanus is indehiscent, that is, it does not burst as that of the Sinapis does, but breaks into joints, each containing a seed. These may be separated by what is termed a *bere* riddle, through which the grain passes while the joints are retained. The best winnowing machines are now provided with both these sifters.

Of the seeds that come into the thrashing mill, the greatest quantity again conveyed to the fields is through inattention to the siftings, sweepings, and other refuse, which are often heedlessly thrown to the pigs, to the dung-hill, straw-court, or compost heap, where, unless the fermentation is higher and more complete than for other reasons is desirable, the vitality of the seeds is not destroyed; and thus the farmer actually propagates weeds, and in such a way too that they cannot fail to flourish amazingly. A little reflexion on this matter would surely lead to the correction of these errors.

that the leaf, from which the epidermis was stripped off, continued to produce oxygen when placed in water, containing carbonic acid gas, and the globules of air rose from the denuded parenchyma; and it is shewn both from the experiments of Sennebier and Woodhouse, that the leaves most abundant in parenchymatous parts produce most oxygen in water impregnated with carbonic acid.*

Some few plants† will vegetate in an artificial atmosphere, consisting principally of carbonic acid, and many will grow for some time in air, containing from one-half to one-third; but they are not so healthy as when supplied with smaller quantities of this elastic substance.‡

Plants exposed to light have been found to produce oxygen gas in an elastic medium and in water, containing no carbonic acid gas; but in quantities much smaller than when carbonic acid gas was present.

In the dark no oxygen gas is produced by plants, whatever be the elastic medium to which they are exposed; and no carbonic acid absorbed In most cases, on the contrary, oxygen gas, if it be present, is absorbed and carbonic acid gas is produced.

In the changes that take place in the composition of the organize parts, it is probable that saccharine compounds are principally forme during the absence of light; gum, woody fibre, oils, and resins, durin its presence; and the evolution of carbonic acid gas, or its formatio during the night, may be necessary to give greater solubility to certai compounds in the plant. I once suspected that all the carbonic acid ga produced by plants in the night, or in shade, might be owing to the deca of some part of the leaf, or epidermis; but the recent experiments of M D. Ellis are opposed to this idea; and I found that a perfectly health plant of celery, placed in a given portion of air for a few hours onl occasioned a production of carbonic acid gas, and an absorption oxygen.

Some persons have supposed that plants exposed in the free atmosphe to the vicissitudes of sunshine and shade, light and darkness, consum more oxygen than they produce, and that their permanent agency upon air similar to that of animals; and this opinion is espoused by the writer c the subject I have just quoted, in his ingenious researches on vegetatio But all experiments brought forward in favour of this idea, and partic larly his experiments, have been made under circumstances unfavourab to accuracy of result. The plants have been confined and supplied wi food in an unnatural manner; and the influence of light upon them h been very much diminished by the nature of the media through which passed. Plants confined in limited portions of atmospheric air soon b come diseased; their leaves decay, and by their decomposition th

* It appears to be established by numerous recent experiments, that leaves herbaceous plants, and particularly membraneous leaves, as well as those wh surfaces are villous, hairy or tomentose, and generally the less polished and wa leaves, both evaporate most water, and evolve most oxygen; while very glo and lustrous leaves, especially those of evergreens, evaporate least water, a evolve least oxygen.

† I found the Arenaria tenuifolia to produce oxygen in carbonic acid, wh was nearly pure.—D.

‡ Plants placed in sunshine or bright day-light can live and thrive in air c taining a considerable proportion of carbonic acid; but in the shade, or in or nary circumstances, any increase above the proportion usually found in the is prejudicial.

rapidly destroy the oxygen of the air. In some of the early experiments of Dr. Priestly before he was acquainted with the agency of light upon leaves, air that had supported combustion and respiration, was found purified by the growth of plants when they were exposed in it for successive days and nights; and his experiments are the more unexceptionable, as the plants, in many of them, grew in their natural states; and shoots, or branches from them, only were introduced through water into the confined atmosphere. *

* The opinion stated in the text that Ellis's experiments were not so conducted that the accuracy of the results could be relied on, has been completely borne out by the more recent and accurate results of Dr. Daubeny. By operating with large vessels, and particularly by removing the plants as soon as they became sickly, he has shewn, "that plants, even in a confined atmosphere, do in reality add a great deal more oxygen to the air than they abstract from it, whilst the amount of carbonic acid which may be introduced undergoes at the same time a corresponding diminution," and this effect he "even found to take place in diffused light, as well as under the direct influence of the solar rays, and to be no less common in aquatic than in terrestrial plants." And further, "that when a branch loaded with flowers, as well as leaves, was introduced into a jar containing a certain proportion of carbonic acid, the balance still continued to be in favour of the purifying influence of the vegetable." The following account of one of his most successful experiments is remarkably instructive:—"In a second trial, however, the branch of a healthy lilac growing in the garden was introduced into the same jar, where it was suffered to remain until its leaves were entirely withered. The first day the increase of oxygen in the jar was no more than 0·25 per cent., but on the second it rose to 25·0. At night it sunk to nearly 22·0 per cent., but the next evening it had again risen to 27·0. This was the maximum of its increase, for at night it sunk to 26·0, and in the morning exhibited signs of incipient decay. Accordingly, in the evening, the oxygen amounted only to 26·5; and the next evening to 25·5; the following one to 24·75; and the one next succeeding it had fallen to the point at which it stood at the commencement, or to 21·0 per cent. The reason of this decrease was, however, very manifest from the decay and falling off of the leaves; so that this circumstance does not invalidate the conclusion which the preceding experiments concur in establishing, namely, that in fine weather a plant, so long at least as it continues healthy, adds considerably to the oxygen of the air when carbonic acid is freely supplied. In the last instance quoted, the exposed surface of all the leaves inclosed in the jar, which were about fifty in number, was calculated at not more than 300 square inches, and yet there must have been added to the air of the jar as much as 26 cubic inches of oxygen, in consequence of the action of this surface upon the carbonic acid introduced. [The carbonic acid was every morning made equivalent to five or six per cent.] But there is reason to believe, that even under the circumstances above stated (which appear more favourable to the due performance of the functions of life than those to which Mr Ellis's plants were subjected,) the amount of oxygen evolved was much smaller than it would have been in the open air, for I have succeeded by introducing several plants into the same jar of air in pretty quick succession, in raising the amount of oxygen contained from twenty-one to thirty-nine per cent., and probably had not even then attained the limit to which the increase of this constituent might have been brought. How great then must be the effect of an entire tree in the open air under favourable circumstances! and we must recollect that, *cæteris paribus*, the circumstances will be favourable to the exertion of the vital energies of the plant, within certain limits at least, in proportion as animal respiration and animal putrefaction furnish to it a supply of carbonic acid"—*Three Lectures on Agriculture.*

But apart from all eudiometric investigations, the simplest, and, at the same time, the most satisfactory proof of these two facts, that under the influence of

I have made some few researches on this subject, and I shall describe their results. On the 12th of July, 1800, I placed a turf four inches square, clothed with grass, principally meadow fox-tail, and white clover, in a porcelain dish, standing in a shallow tray filled with water; I then covered it with a jar of flint glass, containing 380 cubical inches of common air in its natural state. It was exposed in a garden, so as to be liable to the same changes with respect to light as in the common air. On the 20th of July the results were examined. There was an increase of the volume of the gas, amounting to fifteen cubical inches; but the temperature had changed from 64° to 71°; and the pressure of the atmosphere, which on the 12th had been equal to the support of 30·1 inches of mercury, was now equal to that of 30·2. Some of the leaves of the white clover, and of the fox-tail were yellow, and the whole appearance of the grass less healthy than when it was first introduced. A cubical inch of the gas, agitated in lime-water, gave a slight turbidness to the water; and the absorption was not quite $\frac{1}{150}$ of its volume. 100 parts of the residual gas exposed to a solution of green sulphate of iron, impregnated with nitrous gas, a substance which rapidly absorbs oxygen from air, occasioned a diminution to 80 parts. 100 parts of the air of the garden occasioned a diminution to 79 parts.

If the results of this experiment be calculated upon it, it will appear that the air had been slightly deteriorated by the action of the grasses. But the weather was unusually cloudy during the progress of the experiment; the plants had not been supplied in a natural manner with carbonic acid gas; and the quantity formed during the night, and by the action of the faded leaves, must have been partly dissolved by the water; and that this was actually the case, I proved by pouring lime-water into the water,

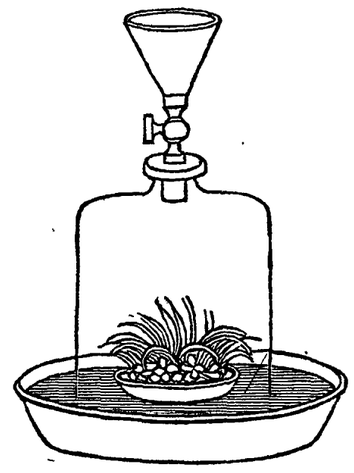
light, plants evolve oxygen, aud that they evolve more than they consume, is derived from the growth of plants under water. Every botanist and angler must have observed when wading in rivers or lakes, that, in sunshine, or even in bright diffused day-light, the surface of green *confervæ* (crow-silk) is covered with minute globules of gas, which rise to the surface of the water the moment the beds of confervæ are trod upon or disturbed. The gas referred to can be easily collected, by filling and inverting under water a bell-glass or tumbler, and moving it along the surface of the plants so that the gas may rise in it. Any of the usual tests of oxygen—as introducing an ignited splinter of wood—will at once demonstrate that the gas is oxygen.

That plants evolve more oxygen than they consume, has been satisfactorily proved by Liebig, in reference to a well-known, although previously unheeded phenomenon. "When pools and ditches, the bottoms of which are covered with growing plants, freeze upon their surface in winter, so that the water is completely excluded from the atmosphere by a clear stratum of ice, small bubbles of gas are observed to escape continually, during the day, from the points of the leaves and twigs. The bubbles are seen most distinctly when the rays of the sun fall upon the ice; they are very small at first, but collect under the ice and form larger bubbles. They consist of pure oxygen gas. Neither during the night, nor during the day when the sun does not shine, are they observed to diminish in quantity. The source of the oxygen is the carbonic acid dissolved in the water, by the decay of vegetable substances contained in the soil. If these plants absorb oxygen during the night, it can be in no greater quantity than that which the surrounding water holds in solution, for the gas, which has been exhaled, is not again absorbed. The action of water plants cannot be supposed to form an exception to a great law of nature, and the less so, as the different action of aërial plants upon the atmosphere is very easily explained."—*Agricultural Chemistry, 2d Edition, p.* 36.

when an immediate precipitation was occasioned. The increase of azote I am inclined to attribute to common air disengaged from the water.

The following experiment I consider as conducted under circumstances more analogous to those existing in nature. A turf four inches square, from an irrigated meadow, clothed with common meadow grass, meadow fox-tail grass, and vernal meadow grass, was placed in a porcelain dish, which swam on the surface of water impregnated with carbonic acid gas. A vessel of thin flint glass, of the capacity of 230 cubical inches, having a funnel furnished with a stop-cock inserted in the top, was made to cover the grass; and the apparatus was exposed in an open place; a small quantity of water was daily supplied to the grass by means of the stop-cock (Fig. 35). Every day likewise a certain quantity of water was removed by a siphon, and water saturated with carbonic acid gas supplied in its place; so that it may be presumed, that a small quantity of carbonic acid gas was constantly present in the receiver. On the 7th of July, 1807, the first day of the experiment, the weather was cloudy in the morning, but fine in the afternoon; the thermometer at 67°, the barometer 30·2: towards the evening of this day a slight increase of the gas was perceived, the next three days were bright; but in the morning of the 11th the sky was clouded; a considerable increase of the volume of the gas was now observed: the 12th was cloudy, with gleams of sunshine; there was still an increase, but less than in the bright days; the 13th was bright. About nine o'clock A.M., on the 14th, the receiver was quite full; and considering the original quantity in the jar, it must have been increased by at least 30 cubical inches of elastic fluid: at times during this day globules of gas escaped. At ten on the morning of the 15th, I examined a portion of the gas; it contained less than $\frac{1}{50}$ of carbonic acid gas: 100 parts of it exposed to the impregnated solution left only 75 parts; so that the air was four per cent. purer than the air of the atmosphere.

Fig. 35.



I shall detail another similar experiment made with equally decisive results. A shoot from a vine, having three healthy leaves belonging to it, attached to its parent tree, was bent so as to be placed under the receiver which had been used in the last experiment; the water confining the common air was kept in the same manner impregnated with carbonic acid gas: the experiment was carried on from August 6th, till August 14th, 1807: during this time, though the weather had been generally clouded, and there had been some rain, the volume of elastic fluid continued to increase. Its quality was examined on the morning of the 15th; it contained $\frac{1}{42}$ of carbonic acid gas, and 100 parts of it afforded 23·5 of oxygen gas.

These facts confirm the popular opinion, that when the leaves of vegetables perform their healthy functions, they tend to purify the atmosphere in the common variations of weather, and changes from light to darkness.

In germination, and at the time of the decay of the leaf, oxygen must be absorbed; but when it is considered how large a part of the surface of the earth is clothed with perennial grasses, and that half of the globe is always exposed to the solar light, it appears by far the most probable opinion, that more oxygen is produced than consumed during the process

of vegetation; and that it is this circumstance which is the principal cause of the uniformity of the constitution of the atmosphere.

Animals produce no oxygen gas during the exercise of any of their functions, and they are constantly consuming it; but the extent of the animal, compared to that of the vegetable, kingdom is very small; and the quantity of carbonic acid gas produced in respiration, and in various processes of combustion and fermentation, bears a proportion extremely minute to the whole volume of the atmosphere:* if every plant during the progress of its life makes a very small addition of oxygen to the air, and occasions a very small consumption of carbonic acid, the effect may be conceived adequate to the wants of nature.

It may occur as an objection to these views, that if the leaves of plants purify the atmosphere, towards the end of autumn, and through the winter, and early spring, the air in our climates must become impure, the oxygen in it diminish, and the carbonic acid gas increase, which is not the case; but there is a very satisfactory answer to this objection. The different parts of the atmosphere are constantly mixed together by winds, which when they are strong, move at the rate of from 60 to 100 miles in an hour. In our winter, the south-west gales convey air, which has been purified by the vast forests and savannas of South America, and which, passing over the ocean, arrives in an uncontaminated state. The storms and tempests which often occur at the beginning, and towards the middle of our winter, and which generally blow from the same quarter of the globe, have a salutary influence. By constant agitation and motion, the equilibrium of the constituent parts of the atmosphere is preserved; it is fitted for the purposes of life; and those events, which the superstitious formerly referred to the wrath of heaven, or the agency of evil spirits, and in which they saw only disorder and confusion, are demonstrated by science, to be ministrations of divine intelligence, and connected with the order and harmony of our system.

I have reasoned, in a former part of this Lecture, against the close analogy which some persons have assumed between the absorption of oxygen and the formation of carbonic acid gas in germination, and in the respiration of the fœtus. Similar arguments will apply against the pursuit of this analogy, between the functions of the leaves of the adult plant, and those of the lungs of the adult animal.† Plants grow vigorously

* See note, page 167.

† Notwithstanding of the warning so distinctly given in the text, the obscurity that still exists in almost all works on Vegetable Physiology regarding the absorption of oxygen and the evolution of carbonic acid has undoubtedly arisen from carrying to an unwarrantable extent the analogy between plants and animals. Plants were observed to evolve oxygen in sunshine and bright day-light; during the night to evolve carbonic acid and absorb oxygen. To account for both phenomena, Burnet and others maintained that plants like animals possess a function of respiration as well as digestion; that oxygen is evolved when digestion is going on, the carbon of carbonic acid being assimilated, but as this function requires the presence of light of considerable intensity it can proceed only by day. To account for the absorption of oxygen and the evolution of carbonic acid during the night, it was affirmed that plants, like animals, respire at all times, absorbing oxygen and evolving carbonic acid, the carbon of the carbonic acid being derived from some of the vegetable tissues; but that it is only during the night, when the process of digestion is not going on, that the expired carbonic acid is apparent.

Of recent writers, Liebig alone boldly denies the existence of a true respiratory function, and explains the evolution of carbonic acid on proper principles. The

only when supplied with light; and most species die if deprived of it. It cannot be supposed that the production of oxygen from the leaf, which is known to be connected with its natural colour, is the exertion of a diseased function, or that it can acquire carbon in the day-time, when it is in most vigorous growth, when the sap is rising, when all its powers of obtaining nourishment are exerted; merely for the purpose of giving it off again in the night, when its leaves are closed, when the motion of the sap is imperfect, and when it is in a state approaching to that of quiescence. Many plants that grow upon rocks, or soils, containing no carbonic matter, can only be supposed to acquire their charcoal from the carbonic acid gas in the atmosphere; and the leaf may be considered at the same time as an organ of absorption, and an organ in which the sap may undergo different chemical changes.

When pure water only is absorbed by the roots of plants, the fluid, in passing into the leaves, will probably have greater power to absorb carbonic acid from the atmosphere. When the water is saturated with carbonic acid gas, some of this substance, even in the sunshine, may be given off by the leaves; but a part of it likewise will be always decomposed, which has been proved by the experiments of M. Sennebier.*

evolution of carbonic acid during the night he shews to be entirely a mechanical process—a necessary consequence of the continued absorption, by the roots, of water holding this gas in solution, and of the evaporation that is constantly going on from the leaves. The absence of light, although it retards the flow of sap and evaporation from the leaves, does not stop these processes; and it is impossible for evaporation of the aqueous portions of the sap to proceed, without the highly volatile carbonic acid assuming the gaseous state, any more than for a piece of cotton or sponge half immersed in a solution of carbonic acid to permit the water to evaporate from its surface while it retains the gas.

With respect to the absorption of oxygen by the leaf, Liebig contends that it is no way analogous to the absorption of oxygen in animal respiration. Most organic bodies to which atmospheric air has access are acted on by its oxygen, that gas being absorbed; but this is not analogous to respiration carried on in the lungs of animals. Recent wood, green leaves plucked from the tree and dried in darkness, absorb oxygen. Leaves that contain essential oils absorb oxygen, and these substances are thereby converted into resins. Acids are formed in plants during the absence of sun-light by the absorption of oxygen from the atmosphere, and it is by this process that the change in the colour of leaves, so well seen in autumn, is gradually effected. Pure woody tissue contains oxygen and hydrogen in the proportions in which they form water, but green leaves and recent woods contain substances in their tissues, capable of being separated, that contain hydrogen in excess. All these substances absorb oxygen from the air, and retain it. In animal respiration the oxygen that is absorbed is again evolved as carbonic acid, the carbon being derived from the body; but the oxygen absorbed during the night by plants is not so evolved, the carbonic acid given out during the night has nothing to do with the oxygen absorbed, or with the tissues of the plant; it never formed part of the tissues. Hence, to insist on a true respiratory function in plants, is to maintain what does not exist, and what tends to obscure and retard just conceptions of vegetable physiology.

* It is common to speak of the oxygen evolved by the leaves of plants in the process of assimilation, as derived from the decomposition of carbonic acid. Many of the tissues of plants, woody tissue for instance, consist of carbon and the elements of water. Here the carbon is obviously derived from carbonic acid, but the oxygen evolved may either be that which was formerly united with carbon in the carbonic acid, or it may be oxygen formerly united with hydrogen in water: in the one case, carbonic acid would undergo decomposition, in the

When the fluid taken up by the roots of plants contains much carbonaceous matter, it is probable that plants may give off carbonic acid from their leaves, even in the sunshine. In short, the function of the leaf must vary according to the composition of the sap passing through it; and according to the nature of the products which are formed from it. When sugar is to be produced, as in early spring at the time of the development of buds and flowers, it is probable that less oxygen will be given off, than at the time of the ripening of the seed, when starch, or gums, or oils are formed; and the process of ripening the seed usually takes place when the agency of the solar light is most intense. When the acid juices of fruits become saccharine in the natural process of vegetation, more oxygen, there is every reason to believe, must be given off, or newly combined, than at other times; for, as it was shewn in the third Lecture, all the vegetable acids contain more oxygen than sugar.* It appears probable, other, water would do so. But, since the quantity of oxygen evolved would be the same in either case, it is not easy to determine the matter. Liebig considers it more likely that it is water that is decomposed; and some of the considerations that give strength to this opinion are: 1st, That in numerous vegetable products, such as the colouring matter of the leaf, essential oils, resins, fatty substances, wax, caoutchouc, &c., which contain hydrogen in large quantity, we have evidence of the decomposition of water, for the hydrogen could be obtained from no other source. 2d, That water is known to be both decomposed and formed in innumerable cases, with remarkable facility, while carbonic acid is much more difficult to decompose.

* Illustrative of the manner in which such changes may be supposed to take place, a few instances may be given. They are as yet merely speculative. Starch contains oxygen and hydrogen in the ratio in which they exist in water, it is represented by the formula C_{12} H_{10} O_{10}. On the supposition that the carbon is derived from carbonic acid, and that this gas undergoes decomposition, its oxygen being evolved while the carbon combines with water to form starch, 12 equivalents of carbonic acid and 10 of water would afford 1 equivalent of starch, with the evolution of 24 equivalents of oxygen, thus:—

12 equivalents carbonic acid,	C_{12}	O_{24}	yield 1 equivalent starch,	C_{12} H_{10} O_{10}	
10 equivalents water,	H_{10}	O_{10}	24 eqts. oxygen,		O_{24}
	C_{12} H_{10} O_{34}.			C_{12} H_{10} O_{34}	

Again, on the supposition that water is decomposed, its oxygen being evolved while its hydrogen combines with the oxygen of the carbonic acid to form starch and water, the same result will be obtained. For let 24 equivalents of water undergo decomposition, yielding their 24 of oxygen to the air, while their hydrogen reacts on 12 equivalents of carbonic acid, there would be formed 1 equivalent of starch and 14 equivalents of water, thus:—

12 equivalents carbonic acid,	C_{12}	O_{24}	yield 1 equivalent starch,	C_{12} H_{10} O_{10}	
24 equivalents water,	H_{24}	O_{24}	14 equivalents water,		H_{14} O_{14}
			24 eqts. oxygen,		O_{24}
	C_{12} H_{24} O_{48}			C_{12} H_{24} O_{48}	

To illustrate the fact mentioned in the text, that different quantities of oxygen will be evolved during the formation of differently constituted products, it may be well to contrast the action that may be supposed to take place during the formation of tartaric acid. This acid consists of carbon and the elements of water, but not in the proportions in which they are found in that substance; here. the oxygen is in excess. Tartaric acid is represented by the formula C_8 H_4 O_{10}, and an equivalent of it would be formed by the reaction of 8 equi-

that in some cases, in which oily and resinous bodies are formed in vegetation, water may be decomposed; its oxygen set free, and its hydrogen absorbed.

I have already mentioned, that some plants produce oxygen in pure water; Dr. Ingenhousz found this to be the case with species of the confervæ; I have tried the leaves of many plants, particularly those that produce volatile oils. When such leaves are exposed in water saturated with oxygen gas, oxygen is given off in the solar light; but the quantity is very small and always limited; nor have I been able to ascertain with

valents of carbonic acid, and 4 of water, 10 equivalents of oxygen being liberated, thus:—

8 equivalents carbonic acid,	C_8	O_{16}	yield	1 eqt. tartaric acid,	C_8 H_4	O_{10}
4 equivalents water,	H_4	O_4		10 equivalents oxygen,		O_{10}
	C_8 H_4	O_{20}			C_8 H_4	O_{20}

Or according to the other view in which water is supposed to afford the liberated oxygen; 10 equivalents of water would be decomposed, evolving 10 equivalents of oxygen, while the hydrogen would combine with the carbonic acid to form 1 equivalent of tartaric acid and 6 of water, thus:—

8 equivalents of carbonic acid,	C_8	O_{16}	yield	1 eqt. tartaric acid,	C_8 H_4	O_{10}
10 equivalents water,	H_{10}	O_{10}		6 equivalents water,	H_6	O_6
				10 equivalents oxygen,		O_{10}
	C_8 H_{10}	O_{26}			C_8 H_{10}	O_{26}

In the case of the formation of starch, it was shewn, that from the fixing of 12 equivalents of carbon, 24 equivalents of oxygen were evolved; while, in regard to the formation of tartaric acid, for the fixing of the same quantity of carbon, only 15 equivalents of oxygen are set free. In like manner it might be shewn, that when compounds containing an excess of hydrogen are formed, the largest quantity of oxygen is eliminated.

During the ripening of fruits, oxygen is absorbed and carbonic acid evolved; acid previously existing in large quantity disappears, and is replaced by grape-sugar. The presence of acid in unripe fruits is fully evinced by the taste; and that the influence of the sun is the cause of its conversion into sugar, is shewn by the greater sourness of fruits in cloudy and sunless seasons. Tropical countries, too, where the solar light is intense, are celebrated for the number of their fruits. In such fruits as contain tartaric acid, this change may be explained on the supposition that 6 equivalents of absorbed oxygen, and 2 equivalents of water react on 3 equivalents of tartaric acid, producing 1 equivalent of grape-sugar with the evolution of 12 equivalents of carbonic acid, thus:—

3 equivalents tartaric acid,	C_{24} H_{12}	O_{30}	yield	1 eqt. grape-sugar,	C_{12} H_{14}	O_{14}
2 equivalents water,	H_2	O_2		12 eqts. carbonic acid,	C_{12}	O_{24}
6 equivalents oxygen,		O_6				
	C_{24} H_{14}	O_{38}			C_{24} H_{14}	O_{38}

Some fruits are capable of ripening off the tree, others are not. In cases where the unripe fruit contains all the constituents, which, together with the oxygen of the air, form ripe fruit, all that is necessary for preserving the fruits for a time, is to keep them in a cool atmosphere free from oxygen. A method recommended by Lindley, of absorbing the oxygen from the air in the bottles or vessels in which the fruit to be preserved is shut up, by means of a paste of sulphate of iron, quicklime, and water, succeeds remarkably well; and in some cases, filling the bottles with carbonic acid gas answers the same purpose. After a certain time, however, varying with the kind of fruit, changes take place on the unripe fruit that prevent its ripening when exposed to air; nor is this to be wondered at, when the instability of such organised bodies is considered.

certainty, whether the vegetative powers of the leaf were concerned in the operation, though it seems probable. I obtained a considerable quantity of oxygen in an experiment made fifteen years ago, in which vine leaves were exposed to pure water; but on repeating the trial often since, the quantities have always been very much smaller; I am ignorant whether this difference is owing to the peculiar state of the leaves, or to some confervæ which might have adhered to the vessel, or to other sources of fallacy.*

The most important and most common products of vegetables, mucilage, starch, sugar, and woody fibre, are composed of water, or the elements of water in their due proportion, and charcoal; and these, or some of them, exist in all plants; and the decomposition of carbonic acid, and the combination of water in vegetable structures, are processes which must occur almost universally.

When glutenous and albuminous substances exist in plants, the azote they contain may be suspected to be derived from the atmosphere: but no experiments have been made which prove this; they might easily be instituted upon mushrooms and funguses.†

* Oxygen is readily evolved, when, in place of pure water, the leaves are exposed in water containing carbonic acid in solution.

† See note, page 166.—Nitrogen, although the largest constituent of atmospheric air, does not appear to be directly absorbed by plants for the purpose of assimilation. As all water contains a small quantity of atmospheric air in solution nitrogen must be taken up by the roots of plants; and to this source is to be traced the nitrogen which in many cases has been observed to be given off by the leaves. But the atmosphere contains nitrogen in other forms from which plants obtain this substance. Ammonia is uniformly present in rain water, although its amount varies considerably according to various circumstances. Ammonia consists of nitrogen and hydrogen, and is decomposed with great facility. During the decay of plants, and particularly of animal bodies, ammonia is evolved, and thus the supply is kept up; it is also evolved in considerable quantity from the interior of the earth in volcanic districts. It is to the ammonia of the air that plants, especially those of extra-tropical countries, are chiefly indebted for their nitrogen.

Nitric acid is another substance that has frequently been detected in rain water, particularly after thunder storms, and which is supposed to arise from the oxygen and nitrogen of the air uniting through the agency of electricity; or from the union of the oxygen of the air with the nitrogen of ammonia. Nitric acid, like ammonia, is a product of the decomposition of organic bodies, particularly within the tropics, and hence, alkaline nitrates occur in the soil. Nitrates are known to be excellent fertilisers, and if these salts are decomposed in the interior of plants, this will form another source of nitrogen.

One of the clearest proofs that there must exist some great atmospheric source of nitrogen is, that in crops grown in soils whose nitrogen may be regarded as a constant quantity, or what is the same thing, which contain at the close of the rotation the same quantity as at the beginning, the nitrogen contained in the produce reaped during a rotation considerably exceeds that furnished by the manure. Boussingault (*Annales de Chimie*, 1841) shews, that in a five course rotation, consisting of 1 potatoes, (dunged,) 2 wheat, 3 clover, 4 wheat, succeeded by an interpolated autumnal crop of turnips, and 5 oats, the weight of nitrogen contained in the whole crops amounted to 250·7 kilogrammes per hectare, while that contained by the manure was only 203·2 killogrammes; which, reduced to pounds avoirdupois per imperial acre, gives 223·7 lbs. in the crops, and 181·3 lbs. in the manure; shewing a gain of nitrogen from atmospheric sources of 42·4 lbs. per imperial acre in the course of this rotation. In other rotations mentioned in the same paper the increase is considerably greater.

In cases in which buds are formed, or shoots thrown forth from roots, oxygen appears to be uniformly absorbed, as in the germination of seeds. I exposed a small potato moistened with common water to 24 cubical inches of atmospherical air, at a temperature of 59°. It began to throw forth a shoot on the third day; when it was half an inch long I examined the air; nearly a cubical inch of oxygen was absorbed, and about three-fourths of a cubical inch of carbonic acid formed. The juices in the shoot separated from the potato, had a sweet taste; and the absorption of oxygen, and the production of carbonic acid, were probably connected with the conversion of a portion of starch into sugar. When potatoes that have been frozen are thawed, they become sweet; probably oxygen is absorbed in this process; if so, the change may be prevented by thawing them out of the contact of air; under water, for instance, that has been recently boiled.

In the tillering of corn, that is, the production of new stalks round the original plume, there is every reason to believe that oxygen must be absorbed; for the stalk at which the tillering takes place, always contains sugar, and the shoots arise from a part deprived of light. The drill husbandry favours this process; for loose earth is thrown by hoeing round the stalks: they are preserved from light, and yet supplied with oxygen. I have counted from forty to one hundred and twenty stalks produced from a grain of wheat, in a moderately good crop of drilled wheat. And we are informed by Sir Kenelm Digby, in 1660, that there was in the possession of the Fathers of the Christian Doctrine at Paris, a plant of barley, which they, at that time, kept by them as a curiosity, and which consisted of 249 stalks springing from one root, or grain, and in which they counted above 18,000 grains, or seeds of barley.

The great increase which takes place in the transplantation of wheat, depends upon the circumstance, that each layer thrown out in tillering may be removed, and treated as a distinct plant. In the Philosophical Transactions, Vol. LVIII, page 203, the following statement may be found: Mr C. Miller, of Cambridge, sowed some wheat on the 2d of June, 1766; and on the 8th of August, a plant was taken and separated into 18 parts, and replanted; these plants were again taken up, and divided in the months of September and October, and planted separately to stand the winter, which division produced 67 plants. They were again taken up in March and April, and produced 500 plants; the number of ears thus formed from one grain of wheat was 21,109, which gave three pecks and three quarters of corn that weighed 47 lbs. 7 ozs.; and that were estimated at 576,840 grains.

It is evident from the statements just given, that the change which takes place in the juices of the leaf by the action of the solar light, must tend to increase the proportion of inflammable matter to their other constituent parts. And the leaves of the plants that grow in darkness, or in shady places, are uniformly pale; their juices are watery and saccharine, and they do not afford oils or resinous substances. I shall detail an experiment on this subject.

I took an equal weight, 400 grains, of the leaves of two plants of endive, one bright green, which had grown fully exposed to light, and the other almost white, which had been secluded from light by being covered with a box; after being both acted upon for some time by boiling water, in the state of pulp, the undissolved matter was dried, and exposed to the action of warm alcohol. The matter from the green leaves gave it a tinge of olive; that from the pale leaves did not alter its colour. Scarcely any

solid matter was produced by evaporation of the alcohol that had been digested on the pale leaves; whereas by the evaporation of that from the green leaves, a considerable residuum was obtained; five grains of which were separated from the vessel in which the evaporation was carried on; they burnt with flame, and appeared partly matter analogous to resin. 53 grains of woody fibre were obtained from the green leaves, and only 31 from the pale leaves.

It has been mentioned in the third Lecture, that the sap probably, in common cases, descends from the leaves into the bark; the bark is usually so loose in its texture, that the atmosphere may possibly act upon it in the cortical layers; but the changes taking place in the leaves, appear sufficient to explain the difference between the products obtained from the bark and from the alburnum; the first of which contains more carbonaceous matter than the last.

When the similarity of the elements of different vegetable products is considered, according to the views given in the third Lecture, it is easy to conceive how the different organized parts may be formed from the same sap, according to the manner in which it is acted on by heat, light, and air. By the abstraction of oxygen, the different inflammable products, fixed and volatile oils, resins, camphor, woody fibre, &c., may be produced from saccharine or mucilaginous fluids; and by the abstraction of carbon and hydrogen, starch, sugar, the different vegetable acids and substances soluble in water, may be formed from highly combustible and insoluble substances. Even the limpid volatile oils which convey the fragrance of the flower, consist of different proportions of the same essential elements, as the dense woody fibre; and both are formed by different changes in the same organs, from the same materials, and at the same time.*

M. Vauquelin has lately attempted to estimate the chemical changes taking place in vegetation, by analysing some of the organized parts of the horse-chesnut in their different stages of growth. He found in the buds collected, March 7, 1812, tanning principle, and albuminous matter capable of being obtained separately, but when obtained, combining with each other. In the scales surrounding the buds, he found the tanning principle, a little saccharine matter, resin, and a fixed oil. In the leaves fully developed, he discovered the same principles as in the buds; and in addition, a peculiar green resinous matter. The petals of the flower yielded a yellowish resin, saccharine matter, albuminous matter, and a little wax; the stamina afforded sugar, resin, and tannin.

The young chesnuts examined immediately after their formation, afforded a large quantity of a matter which appeared to be a combination of albuminous matter and tannin. All the parts of the plant afforded saline combinations of acetic and phosphoric acids.

M. Vauquelin could not obtain a sufficient quantity of the sap of the horse-chesnut for examination; a circumstance much to be regretted; and he has not stated the relative quantities of the different substances in the buds, leaves, flowers, and seeds. It is probable, however, from his unfinished details, that the quantity of resinous matter is increased in the leaf, and that the white fibrous pulp of the chesnut is formed by the mutual action of albuminous and astringent matter, which probably are supplied by different cells or vessels. I have already mentioned, page 81,

* See note, pages 178-9.

that the cambium, from which the new parts in the trunk and branches appear to be formed, probably owe its powers of consolidation to the mixture of two different kinds of sap; one of which flows upwards from the roots, and the other of which probably descends from the leaves. I attempted, in May 1804, at the time the cambium was forming in the oak, to ascertain the nature of the action of the sap of the alburnum upon the juices of the bark. By perforating the alburnum in a young oak, and applying an exhausting syringe to the aperture, I easily drew out a small quantity of sap. I could not, however, in the same way obtain sap from the bark. I was obliged to recur to the solution of its principles in water, by infusing a small quantity of fresh bark in warm water; the liquid obtained in this way was highly coloured and astringent; and produced an immediate precipitate in the alburnous sap, the taste of which was sweetish, and slightly astringent, and which was colourless.

The increase of trees and plants must depend upon the quantity of sap which passes into their organs; upon the quality of this sap; and on its modification by the principles of the atmosphere. Water, as it is the vehicle of the nourishment of the plant, is the substance principally given off by the leaves. Dr. Hales found, that a sunflower, in one day of twelve hours, transpired by its leaves one pound fourteen ounces of water, all of which must have been imbibed by its roots.

The powers which cause the ascent of the sap have been slightly touched upon in the second and third Lectures. The roots imbibe fluids from the soil by capillary attraction; but this power alone is insufficient to account for the rapid elevation of the sap into the leaves. This is fully proved by the following fact detailed by Dr. Hales, Vol. I. of the Vegetable Statics, page 114. A vine branch of four or five years old was cut through, and a glass tube carefully attached to it; this tube was bent as a syphon, and filled with quicksilver; so that the force of the ascending sap could be measured by its effect in elevating the quicksilver. In a few days it was found, that the sap had been propelled forwards with so much force as to raise the quicksilver to 38 inches, which is a force considerably superior to that of the usual pressure of the atmosphere. Capillary attraction can only be exerted by the surfaces of small vessels, and can never raise a fluid into tubes above the vessels themselves.

I referred in the beginning of the third Lecture to Mr Knight's opinion that the contractions and expansions of the silver grain in the alburnum, are the most efficient cause of the ascent of the fluids contained in its pores and vessels. The views of this excellent physiologist are rendered extremely probable by the facts he has brought forward in support of them. Mr Knight found that a very small increase of temperature was sufficient to cause the fibres of the silver grain to separate from each other, and that a very slight diminution of heat produced their contraction. The sap rises most vigorously in spring and autumn, at the time the temperature is variable; and if it be supposed, that in expanding and contracting, the elastic fibres of the silver grain exercise a pressure upon the cells and tubes containing the fluid absorbed by the capillary attraction of the roots, this fluid must constantly move upwards towards the point where a supply is needed.*

* It has been already remarked, that Knight's view of the rise of the sap is untenable, because it applies only to such plants as possess medullary rays, namely, exogens; and also, because alternate expansions and contractions of the rays, produced by changes in the temperature of the air, would have as much influence in sending the sap down as up.

inventor of the balloon,

The experiments of Montgolfier, the celebrated m[illegible] thite height by a have shewn that water may be raised almost to an indefinit[illegible]ed divisions very small force, provided its pressure be taken off by continu[illegible] suppose, in the column of fluid. This principle, there is great reason to s[illegible]on; of must operate in assisting the ascent of the sap in the cells and vessels plants which have no rectilineal communication, and which every where oppose obstacles to the perpendicular pressure of the sap.*

The changes taking place in the leaves and buds, and the degree of their power of transpiration, must be intimately connected likewise with the motion of the sap upwards. This is shewn by several experiments of Dr. Hales.

A branch from an apple tree was separated and introduced into water, and connected with a mercurial gage. When the leaves were upon it, it raised the mercury by the force of the ascending juices to four inches; but a similar branch, from which the leaves were removed, scarcely raised it a quarter of an inch.

Those trees, likewise, whose leaves are soft and of a spongy texture, and porous at their upper surfaces, displayed by far the greatest powers with regard to the elevation of the sap.

The same accurate philosopher whom I have just quoted, found that the pear, quince, cherry, walnut, peach, gooseberry, water-elder and sycamore, which have all soft and unvarnished leaves, raised the mercury under favourable circumstances from three to six inches. Whereas the elm, oak, chesnut, hazel, sallow, and ash, which have firmer and more glossy leaves, raised the mercury only from one to two inches. And the evergreens and trees bearing varnished leaves, scarcely at all affected it; particularly the laurel and the laurustinus.

It will be proper to mention the facts which shew, that in many cases fluids descend through the bark; they are not of the same unequivocal nature as those which demonstrate the ascent of the sap through the alburnum; yet many of them are satisfactory.

M. Baisse placed branches of different trees in an infusion of madder, and kept them there for a long time. He found in all cases that the wood became red before the bark; and that the bark began to receive no tinge till the whole of the wood was coloured, and till the leaves were affected; and that the colouring matter first appeared above, in the bark immediately in contact with the leaves.

Similar experiments were made by M. Bonnet, and with analogous results, though not so perfectly distinct as those of M. Baisse.

Du Hamel found, that in different species of the pine and other trees, when strips of bark were removed, the upper part of the wound only emitted fluid, whilst the lower part remained dry.

This may likewise be observed in the summer in fruit trees, when the bark is wounded, the alburnum remaining untouched.

I have mentioned in the third Lecture, that when new bark is formed to supply the place of a ring that has been stripped off, it first makes its appearance upon the upper edge of the wound, and spreads slowly downwards; and no new matter appears from below rising upwards, if the experiment has been carefully performed. I say carefully performed; because, if any of the interior cortical layer be suffered to remain com-

* The principle of endosmose already noticed, page 35, affords a much more satisfactory explanation—one more c[illegible]nsistent with the anatomical structure of the vessels, and with the ascertained properties of the tissues.

municating with the upper edge, new bark covered with epidermis will form below this, and appear as if protruded upon the naked alburnum, and formed within the wound; and such a circumstance would give rise to erroneous conclusions.

In the summer of 1804, I examined some elms at Kensington. The bark of many of them had been very much injured, and in some cases more than a square foot had been stripped off. In most of the wounds the formation of the new cortical layers was from above, and gradually extending downwards round the aperture; but in two instances there had been very distinctly a formation of bark towards the lower edge. I was at first very much surprised at this appearance, so contradictory to the general opinion; but on passing the point of a pen-knife along the surface of the alburnum, from below upwards, I found that a part of the cortical layer, which was of the colour of the alburnum, had remained communicating with the upper edge of the wound, and that the new bark had formed from this layer. I have had no opportunity of looking at the trees lately; but I doubt not that the phenomenon may still be observed; for some years must elapse before the new formations will be complete.

In accounting for the experiment of M. Palisot de Beauvois, mentioned in the third Lecture, it may be supposed that the cortical fluid flowed down the alburnum upon the insulated bark, and thus occasioned its increase; or it may be conceived that the bark itself contained sufficient cortical fluid at the time of its separation to form new parts by its action upon the alburnous fluid.

The motion of the sap through the bark seems principally to depend upon gravitation. When the watery particles have been considerably dissipated by the transpiring functions of the leaves, and the mucilaginous, inflammable, and astringent constituents, increased by the agency of heat, light, and air, the continued impulse upwards from the alburnum, forces the remaining inspissated fluid into the cortical vessels, which receive no other supply. In these, from its weight, its natural tendency must be to descend; and the rapidity of the descent must depend upon the general consumption of the fluids of the bark in the living processes of vegetation; for there is every reason to believe, that no fluid passes into the soil through the roots;* and it is impossible to conceive a free lateral communication between the absorbent vessels of the alburnum in the roots, and the transporting or carrying vessels of the bark; for if such a comunication existed, there is no reason why the sap should not rise through the bark as well as through the alburnum; for the same physical powers would then operate upon both.

Some authors have supposed that the sap rises in the alburnum, and descends through the bark in consequence of a power similar to that which produces the circulation of the blood in animals; a force analogous to the muscular force in the sides of the vessels.

Dr. Thomson, in his System of Chemistry, has stated a fact which he considers as demonstrating the irritability of living vegetable systems. When a stalk of spurge *(Euphorbia peplis)* is separated by two incisions from its leaves and roots, the milky fluid flows through both sections. Now, says the ingenious author, it is impossible that this could happen without the living action of the vessels, for they cannot have been more

* It is not meant in this passage to assert that roots possess no excretory power; for this doctrine is distinctly recognised and reasoned on in a subsequent Lecture.

than full; and their diameter is so small, that if it were to continue unaltered, the capillary attraction would be more than sufficient to contain their contents, and consequently not a drop would flow out. Since, therefore, the liquid escapes, it must be driven out by a force different from a common physical force.

To this reasoning it may be answered, that the sides of all the vessels are soft, and capable of collapsing by gravitation, as veins do in animal systems long after they have lost all their vitality; which is an effect totally different from vital or irritable action; and the phenomenon may be compared to that of puncturing a vessel of elastic gum filled with fluid, both above and below; the fluid will make its way through the apertures, though in much larger quantity from the lowest, which I have found is likewise the case with the spurge.

Dr. Barton has stated, that plants grow more vigorously in water in which a little camphor has been infused. This has been brought forward as a fact in favour of the irritability of the vegetable tubular system. It is said that camphor can only be conceived to act as a stimulus, by increasing the living powers of the vessels, and causing them to contract with more energy. But this kind of speculation is very unsatisfactory. Camphor, we know, has a disagreeable pungent taste, and powerful smell; but physicians are far from being agreed whether it is a stimulant or sedative, even in its operations upon the human body. We should have no right whatever, even supposing the irritability of vegetables proved, to conclude, that because camphor assisted the growth of plants, it acted on their living powers; and it is not right to infer the existence of a property proved in no other way, from the operation of uncertain qualities.

That camphor may assist the growth of plants it is easy to conceive; and why should we not consider its efficacy as similar to the efficacy of saccharine and mucilaginous matter, and particularly of oils, to which it is nearly allied in composition; and which afford food to the plant, and not stimulus; which are materials of assimilation, and not of excitement?

The arguments in favour of a contraction similar to muscular action have not then much weight; and besides, there are direct facts which render the opinion highly improbable.

When a single branch of a vine or other tree is introduced in winter into a hot-house, the trunk and the other branches remaining exposed to the cold atmosphere, the sap will soon begin to move towards the buds in the heated branch; these buds will gradually unfold themselves and begin to transpire; and at length open into leaves. Now if any peculiar contractions of the sap vessels or cells were necessary for the ascent of the sap in the vessels, it is not possible that the application of heat to a single branch should occasion irritable action to take place in a trunk many feet removed from it, or in roots fixed in the cold soil: but allowing that the energy of heat raises the fluid merely by diminishing its gravity, increasing the facility of capillary action, and by producing an expansion of the fibres of the silver grain, the phenomenon is in perfect unison with the views advanced in the preceding part of this Lecture.

The ilex, or evergreen oak, preserves its leaves through the winter, even when grafted upon the common oak; and in consequence of the operation of the leaves, there is a certain motion of the sap from the oak towards the ilex, which, as in the last case, seems to be inconsistent with the theory of irritable action.

It is impossible to peruse any considerable part of the Vegetable Statics of Hales, without receiving a deep impression of the dependence of the

motion of the sap upon common physical agencies. In the same tree this sagacious person observed, that in a cold cloudy morning when no sap ascended, a sudden change was produced by a gleam of sunshine, of half an hour; and a vigorous motion of the fluid. The alteration of the wind from south to the north immediately checked the effect. On the coming on of a cold afternoon after a hot day, the sap that had been rising began to fall. A warm shower and a sleet storm produced opposite effects.

Many of his observations likewise shew, that the different powers which act on the adult tree, produce different effects at different seasons.

Thus in the early spring, before the buds expand, the variations of the temperature, and changes of the state of the atmosphere with regard to moisture and dryness, exert their great effects upon the expansions and contractions of the vessels; and then the tree is in what is called by gardeners its bleeding season.

When the leaves are fully expanded, the great determination of the sap is to these new organs. And hence a tree which emits sap copiously from a wound whilst the buds are opening, will no longer emit it in summer when the leaves are perfect; but in the variable weather, towards the end of autumn, when the leaves are falling, it will again possess the power of bleeding in a very slight degree in the warmest days; but at no other times.

In all these circumstances there is nothing analogous to the irritable action of animal systems.

In animal systems the heart and arteries are in constant pulsation. Their functions are unceasingly performed in all climates, and in all seasons; in winter, as well as in spring; upon the arctic snows, and under the tropical suns. They neither cease in the periodical nocturnal sleep, common to most animals; nor in the long sleep of winter, peculiar to a few species. The power is connected with animation, is limited to beings possessing the means of voluntary locomotion; it co-exists with the first appearance of vitality; it disappears only with the last spark of life.

Vegetables may be truly said to be living systems, in this sense, that they possess the means of converting the elements of common matter into organized structures, both by assimilation and reproduction; but we must not suffer ourselves to be deluded by the very extensive application of the word *life*, to conceive, in the life of plants, any power similar to that producing the life of animals. In calling forth the vegetable functions, common physical agents alone seem to operate; but in the animal system these agents are made subservient to a superior principle. To give the argument in plainer language, there are few philosophers who would be inclined to assert the existence of any thing above common matter, any thing immaterial in the vegetable economy. Such a doctrine is worthy only of a poetic form. The imagination may easily give Dryads to our trees, and Sylphs to our flowers; but neither Dryads nor Sylphs can be admitted in vegetable physiology; and for reasons nearly as strong, irritability and animation ought to be excluded.

As the operation of the different physical agents upon the sap vessels of plants ceases, and the fluid becomes quiescent, the materials dissolved in it by heat, are deposited upon the sides of the tubes now considerably diminished in their diameter; and in consequence of this deposition, a nutritive matter is provided for the first wants of the plant in early spring, to assist the opening of the buds, and their expansion, when the motion from the want of leaves is as yet feeble.

This beautiful principle in the vegetable economy was first pointed out by Dr. Darwin; and Mr Knight has given a number of experimental elucidations of it.

Mr Knight made numerous incisions into the alburnum of the sycamore and the birch, at different heights; and in examining the sap that flowed from them, he found it more sweet and mucilaginous in proportion as the aperture from which it flowed was elevated; which he could ascribe to no other cause than to its having dissolved sugar and mucilage, which had been stored up through the winter.

He examined the alburnum in different poles of oak in the same forest; of which some had been felled in winter, and others in summer; and he always found most soluble matter in the wood felled in winter, and its specific gravity was likewise greater.

In all perennial trees this circumstance takes place; and likewise in grasses and shrubs. The joints of the perennial grasses contain more saccharine and mucilaginous matter in winter than at any other season; and this is the reason why the fiorin *(Agrostis alba)* which abounds in these joints, affords so useful a winter food.

The roots of shrubs contain the largest quantity of nourishing matter in the depth of winter; and the bulb in all plants possessing it, is the receptacle in which nourishment is hoarded up during winter.

In annual plants the sap seems to be fully exhausted of all its nutritive matter by the production of flowers and seeds; and no system exists by which it can be preserved.

When perennial grasses are cropped very close by feeding cattle late in autumn, it has been often observed by farmers, that they never rise vigorously in the spring; and this is owing to the removal of that part of the stalk which would have afforded them concrete sap, their first nourishment.*

* The importance of this function has been but indistinctly seen by most writers on Vegetable Physiology. Liebig has given it due prominence; and it deserves the attention of practical men. After the ripening of the seeds, the leaves of many plants continue their functions, nourishment is still taken up, assimilation goes on, but the products have a special destination. Stores of sugar, gum, and starch, are laid up in the wood, to constitute the food of the buds and young leaves in the succeeding spring. This process is called the *ripening of the wood*, and it explains satisfactorily a phenomenon of too frequent occurrence in our variable climate, namely, that after an unusually early winter, the vegetation of the following spring is scanty, and the crop of fruit deficient. In some plants these stores occur chiefly as gum and sugar, in others as starch, and frequently all the three are found together. In seeds, and tubers abounding in starch, it has been shewn that the conversion of this substance into sugar is effected by diastase, which occurs along with it, or what is equivalent to the same thing, is formed by the transformation of gluten. Now, from the fact that in spring the juices of many plants are found to be highly saccharine, and the more so as they ascend the stem, it is inferred that diastase exists in the roots, and that by the ascent of the sap it is carried to the starch laid up in the wood, and converts it into sugar exactly at the time the young buds and growing tissues require it for nourishment. It appears then, that the ordinary buds and the embryo, or young bud enclosed in the seed, are nourished on the same principle; and hence, another reason for adopting du Petit Thouars' view of the buds as *fixed embryos*.

But this process of laying up nourishment in store is not confined to plants with perennial stems, it occurs also, as stated in the text, in perennial grasses, indeed in all rhizocarpous plants. In these, however, the store of nourishment

Ship builders prefer for their purposes that kind of oak timber afforded by trees that have had their bark stripped off in spring, and which have been cut in the autumn or winter following. The reason of the superiority of this timber is, that the concrete sap is expended in the spring in the sprouting of the leaf; and the circulation being destroyed, it is not formed anew; and the wood having its pores free from saccharine matter, is less liable to undergo fermentation from the action of moisture and air.

In perennial trees a new alburnum, and consequently a new system of vessels, is annually produced, and the nutriment for the next year deposited in them; so that the new buds, like the plume of the seed, are supplied with a reservoir of matter essential to their first development.

The old alburnum is gradually converted into heart-wood, and being constantly pressed upon by the expansive force of the new fibres, becomes harder, denser, and at length loses altogether its vascular structure;* and in a certain time obeys the common laws of dead matter, decays, decomposes, and is converted into aeriform and carbonic elements; into those principles from which it was originally formed.

The decay of the heart-wood seems to constitute the great limit to the age and size of trees. And in young branches from old trees, it is much more liable to decompose than in similar branches from seedlings. This is likewise the case with grafts. The graft is only nourished by the sap of the tree to which it is transferred; its properties are not changed by it: the leaves, blossoms, and fruits are of the same kind as if it had vegetated upon its parent stock. The only advantage to be gaincd in this way is the affording to a graft from an old tree a more plentiful and healthy food than it could have procured in its natural state; it is rendered for a time more vigorous, and produces fairer blossoms and richer fruits. But it partakes not merely of the obvious properties, but likewise of the infirmities and dispositions to old age and decay, of the tree whence it sprung.

This seems to be distinctly shewn by the observations and experiments of Mr Knight. He has, in a number of instances, transferred the young scions and healthy shoots from old esteemed fruit-bearing trees to young seedlings. They flourished for two or three years; but they soon became diseased and sickly like their parent trees.

It is from this cause that so many of the apples formerly celebrated for their taste and their uses in the manufacture of cyder are gradually de-

is laid up in the roots, or such parts of the base of the stem as do not perish. It is a rule with good agriculturalists not to depasture too closely, but to leave a considerable *foggage* to shelter the shoots in early spring. That some benefit is derived from the assigned cause there is no doubt, but the principal reason for the rule is that nourishment is laid up in the roots and lower parts of the stem. Nothing can be more prejudicial to the hay crop than to permit sheep to pasture, even for a short time, on the stubble, when clover and grass seeds have been laid down with the white crop. The clover produces rich and juicy stems that lie prostrate on the ground during the first winter, and contain a great portion of the nourishment that will be required as soon as growth sets up in spring; if by a short-sighted policy this store is materially diminished, it should surprise no one that the clover fails.

* The principal cause of the conversion of alburnum into duramen appears to be the filling up of the tissues with incrusting matter. This indeed, is proved by microscopic examination, by the deeper colour which heart-wood generally possesses, and, more satisfactorily still, by macerating it in any solvent by which the colouring and incrusting matter is taken up: the wood is then left in a condition no longer distinguishable from sap-wood.

teriorating, and many will soon disappear. The golden pippin, the red streak, and the moil, so excellent in the beginning of the last century, are now in the extremest stage of their decay; and however carefully they are ingrafted, they merely tend to multiply a sickly and exhausted variety. *

The trees possessing the firmest and the least porous heartwood are the longest in duration.

In general the quantity of charcoal afforded by woods, offers a tolerably accurate indication of their durability; those most abundant in charcoal and earthy matter are most permanent; and those that contain the largest proportion of gaseous elements are the most destructible.

Amongst our own trees, the chesnut and the oak are pre-eminent as to durability; and the chesnut affords rather more carbonaceous matter than the oak.

In old gothic buildings these woods have been sometimes mistaken one for the other; but they may be easily known by this circumstance, that the pores in the alburnum of the oak are much larger and more thickly set, and are easily distinguished; whilst the pores in the chesnut require glasses to be seen distinctly.

In consequence of the slow decay of the heart-wood of the oak and chesnut, these trees under favourable circumstances attain an age which cannot be much short of 1000 years.

The beech, the ash, and the sycamore, most likely never live half as long. The duration of the apple tree is not, probably, much more than 200 years; but the pear tree, according to Mr Knight, lives through double this period; most of our best apples are supposed to have been introduced into Britain by a fruiterer of Henry the Eighth, and they are now in a state of old age.

The oak and chesnut decay much sooner in a moist situation than in a dry and sandy soil; and their timber is less firm. The sap vessels in such cases are more expanded, though less nourishing matter is carried into them; and the general texture of the formations of wood necessarily less

* This ingenious theory, so ably advocated by Knight, and so extensively adopted by physiologists, has of late years met with many opponents; and is not now so generally received as formerly. According to Knight, a graft is to be considered as but a portion of an individual plant placed in very favourable circumstances; and hence, if the variety is not long-lived, neither can the graft be so, although its favourable situation, and careful culture, may postpone the period at which old age will overtake it. Others, while they admit that many of our orchard trees are declining, refuse to attribute the fact to this cause. It has been argued that varieties propagated by cuttings, or by layers or offsets, are, so far as this argument is concerned, in the same condition as grafted trees. That cuttings have often been taken from comparatively short-lived trees—willows for instance—in extreme old age, and have produced trees as large, sound and healthy as the parent trees. That many of the best gooseberry and raspberry bushes of gardens, have been produced from cuttings for a very long period, without deterioration, and yet they are short-lived plants; and the argument from some of the favourites of the flower-garden, propagated in the same way, is still more conclusive.

But although it were fully proved that Knight's view is a mistaken one, it ought not to diminish our gratitude for his unrivalled efforts in producing many of the most valuable and esteemed new varieties by selection from the seed and by judicious crossing. To whatever cause the ultimate deterioration of cultivated varieties is due, the methods pursued by this distinguished botanist are the only ones by which the evil can be remedied.

firm. Such wood splits more easily, and is more liable to be affected by variations in the state of the atmosphere.

The same trees, in general, are much longer lived in the northern than in the southern climates. The reason seems to be, that all fermentation and decomposition are checked by cold; and at very low temperatures both animal and vegetable matters altogether resist putrefaction: and in the northern winter, not only vegetable life, but likewise vegetable decay, must be at a stand.

The antiputrescent quality of cold climates is fully illustrated in the instances of the rhinoceros and mammoth lately found in Siberia, entire beneath the frozen soil, in which they must probably have existed from the time of the deluge. I examined a part of the skin of the mammoth sent to this country, on which there was some coarse hair; it had all the chemical characters of recently dried skin.

Trees that grow in situations much exposed to winds, have harder and firmer wood than such as are considerably sheltered. The dense sap is determined by the agitation of the smaller branches to the trunk and large branches; where the new alburnum formed is consequently thick and firm. Such trees abound in the crooked limbs fitted for forming knee-timber, which is necessary for joining the decks and the sides of ships. The gales in elevated situations gradually act, so as to give the tree the form best calculated to resist their effects. And the mountain oak rises robust and sturdy; fixed firmly in the soil, and able to oppose the full force of the tempest.

The decay of the best varieties of fruit-bearing trees which have been distributed through the country by grafts, is a circumstance of great importance. There is no mode of preserving them; and no resource, except that of raising new varieties by seeds.

Where a species has been ameliorated by culture, the seeds it affords, other circumstances being similar, produce more vigorous and perfect plants; and in this way the great improvements in the productions of our fields and gardens seem to have been occasioned.

Wheat in its indigenous state, as a natural production of the soil, appears to have been a very small grass:* and the case is still more remarkable with the apple and the plum. The crab seems to have been the parent of all our apples. And two fruits can scarcely be conceived more different in colour, size, and appearance than the wild plum and the rich magnum bonum.

The seeds of plants exalted by cultivation always furnish large and improved varieties; but the flavour, and even the colour of the fruit seems to be a matter of accident. Thus a hundred seeds of the golden pippin will all produce fine large-leaved apple-trees, bearing fruit of a considerable size; but the tastes and colours of the apples from each will be different, and none will be the same in kind as those of the pippin itself. Some will be sweet, some sour, some bitter, some mawkish, some aromatic; some yellow, some green, some red, and some streaked. All

* This statement rests on an observation of Sir J. Banks. Among a collection of seeds from India, there was a small packet labelled hill-wheat. The seeds were not larger than those of our indigenous grasses, but resembled wheat in form and structure. These seeds were sown, and produced a crop of spring wheat of the ordinary size and appearance. It would have been interesting to have traced the locality from which these seeds came, but on inquiry, no definite information regarding them could be obtained.

the apples will, however, be much more perfect than those from the seeds of a crab, which produce trees all of the same kind, and all bearing sour and diminutive fruit.

The power of the horticulturist extends only to the multiplying excellent varieties by grafting. They cannot be rendered permanent; and the good fruits at present in our gardens, are the produce of a few seedlings, selected probably from hundreds of thousands; the results of great labour and industry, and multiplied experiments. *

The larger and thicker the leaves of a seedling, and the more expanded its blossoms, the more it is likely to produce a good variety of fruit. Short-leaved trees should never be selected; for these approach nearer to the original standard: whereas the other qualities indicate the influence of cultivation.

In the general selection of seeds, it would appear that those arising from the most highly cultivated varieties of plants, are such as give the most vigorous produce: but it is necessary from time to time to change, and as it were, to cross the breed.

By applying the pollen, or dust of the stamina from one variety to the pistil of another of the same species, a new variety may be easily produced; and Mr Knight's experiments seem to warrant the idea, that great advantages may be derived from this method of propagation.

Mr Knight's large peas produced by crossing two varieties, are celebrated amongst horticulturists, and will, I hope, soon be cultivated by farmers.

I have seen several of his crossed apples, which promise to rival the best of those which are gradually dying away in the cyder countries.

And his experiments on the crossing of wheat, which is very easily effected, merely by sowing the different kinds together, † lead to a result which is of considerable importance. He says, in the Philosophical Transactions for 1799, "in the years 1795 and 1796, when almost the whole crop of corn in the island was blighted, the varieties obtained by crossing *alone* escaped, though sown in several soils, and in very different situations."

* Although an inferior or wild plant, taken young into cultivation, and managed with skill, becomes more vigorous and highly developed, it does not appear that any very marked improvement takes place on the fruit. By sowing large quantities of the seeds of a wild, and especially of a cultivated plant, numerous varieties will occur, and it is by careful selection among these, that the varieties in cultivation have been obtained. New and useful varieties do occur among wild plants, but it is remarkable how greatly the chance is multiplied in those that have been long in a state of domestication.

† In exact experiments on hybridation, it is unsafe to trust to the chance of sowing the two varieties together. The flower buds must be carefully opened, and the anthers removed from the plant, to whose stigma the pollen is to be applied, prior to the bursting of its own anthers. The flower is then left till the stigma is sufficiently matured, and the pollen from the other variety is then applied. Should the anthers of the male parent burst before the stigma in the opened flower is far enough advanced to admit of its application, the pollen may be collected and kept in well stopt glass tubes without any risk of deterioration. If impregnation has not been effected in all the flowers, it is better to cut away those that have not been operated on, as it saves much trouble in selection when the seeds are afterwards sown, and it also secures more healthy and vigorous seeds. Insects, too, must be guarded against, if the flowers are such as attract them, and the experiments should be carried on at a distance from other plants of the same or of nearly allied kinds.—See note pages 40-1.

The processes of gardening for increasing the number of fruit-bearing branches, and for improving the fruit upon particular branches, will all admit of elucidation from the principles that have been advanced in this Lecture.

By making trees espaliers, the force of gravity is particularly directed towards the lateral parts of the branches, and more sap determined towards the fruit buds; and hence they are more likely to bear when in a horizontal than when in a vertical position.

The twisting of a wire, or tying a thread round a branch, has been often recommended as a means of making it produce fruit. In this case the descent of the sap in the bark must be impeded above the ligature; and more nutritive matter consequently retained and applied to the expanding parts.

In engrafting, the vessels of the bark of the stock and the graft cannot so perfectly come in contact as the alburnous vessels, which are much more numerous, and equally distributed; hence the circulation downwards is probably impeded, and the tendency of the graft to evolve its fruit-bearing buds increased.

By lopping trees, more nourishment is supplied to the remaining parts; for the sap flows laterally as well as perpendicularly. The same reasons will apply to explain the increase of the size of fruits by diminishing the number upon a tree.

As plants are capable of amelioration by peculiar methods of cultivation, and of having the natural term of their duration extended; so in conformity to the general law of change, they are rendered unhealthy by being exposed to peculiar unfavourable circumstances, and liable to premature old age and decay.

The plants of warm climates transported into cold ones, or of cold ones transported into warm ones, if not absolutely destroyed by the change of situation, are uniformly rendered unhealthy.

Few of the tropical plants, as is well known, can be raised in this country, except in hot-houses. The vine during the whole of our summer may be said to be in a feeble state with regard to health; and its fruit, except in very extraordinary cases, always contains a superabundance of acid. The gigantic pine of the north, when transported into the equatorial climates, becomes a degenerated dwarf; and a great number of instances of the same kind might be brought forward.

Much has been written, and many very ingenious remarks have been made by different philosophers, upon what have been called the habits of plants. Thus, in transplanting a tree, it dies or becomes unhealthy, unless its position with respect to the sun is the same as before. The seeds brought from warm climates germinate here much more early in the season than the same species brought from cold climates. The apple tree from Siberia, where the short summer of three months immediately succeeds the long winter, in England, usually puts forth its blossoms in the first year of its transplantation, on the appearance of mild weather; and is often destroyed by the late frosts of the spring.

It is not difficult to explain this principle so intimately connected with the healthy or diseased state of plants.

The organization of the germ, whether in seeds or buds, must be different according as more or less heat or alternations of heat and cold have affected it during its formation; and the nature of its expansion must depend wholly on this organization. In a changeable climate the formations will have been interrupted, and in different successive layers. In an

equable temperature they will have been uniform; and the operation of new and sudden causes will of course be severely felt.

The disposition of trees may, however, be changed gradually in many instances; and the operation of a new climate in this way be made supportable. The myrtle, a native of the South of Europe, inevitably dies if exposed in the early state of its growth to the frosts of our winter; but if kept in a green-house during the cold seasons for successive years, and gradually exposed to low temperatures, it will, in an advanced stage of growth, resist even a very severe cold. And in the south and west of England the myrtle flourishes, produces blossoms and seeds, in consequence of this process, as an unprotected standard tree; and the layers from such trees are much more hardy than the layers from myrtles reared within doors.

The arbutus, probably originally from similar cultivation, has become the principal ornament of the lakes of the south of Ireland. It thrives even in bleak mountain situations; and there can be little doubt but that the offspring of this tree inured to a temperate climate might be easily spread in Britain.

The same principles that apply to the effects of heat and cold will likewise apply to the influence of moisture and dryness. The layers of a tree habituated to a moist soil will die in a dry one: even though such a soil is more favourable to the general growth of the species. And, as was stated, page 116, trees that have been raised in the centre of woods are sooner or later destroyed, if exposed in their adult state to blasts, in consequence of the felling of the surrounding timber.

Trees, in all cases, in which they are exposed in high and open situations to the sun, the winds, and the rain, as I just now noticed, become low and robust, exhibiting curved limbs, but never straight and graceful trunks. Shrubs and trees, on the contrary, which are too much sheltered, too much secluded from the sun and wind, extend exceedingly in height; but present at the same time slender and feeble branches, their leaves are pale and sickly, and in extreme cases they do not bear fruit. The exclusion of light alone is sufficient to produce this species of disease, as would appear from the experiments of Bonnet. This ingenious physiologist sowed three seeds of the pea in the same kind of soil; one he suffered to remain exposed to the free air; the other he inclosed in a tube of glass; and the third in a tube of wood. The pea in the tube of glass sprouted, and grew in a manner scarcely at all different from that under usual circumstances; but the plant in the tube of wood deprived of light, became white, and slender, and grew to a much greater height.

The plants growing in a soil incapable of supplying them with sufficient manure or dead organised matter, are generally very low; having brown or dark green leaves, and their woody fibre abounds in earth. Those vegetating in peaty soils, or in lands too copiously supplied with animal or vegetable matter, rapidly expand, produce large bright green leaves, abound in sap, and generally blossom prematurely.

Where a land is too rich for corn it is not an uncommon practice to cut down the first stalks, as by these means its exuberance is corrected, and it is less likely to fall before the grain is ripe; excess of poverty or of richness is almost equally fatal to the hopes of the farmer; and the true constitution of the soil for the best crop is that in which the earthy materials, the moisture and manure, are properly associated; and in which the decomposable vegetable or animal matter does not exceed one-fourth of the weight of the earthy constituents.

The canker, or erosion of the bark and wood, is a disease produced often in trees by a poverty of soil; and it is invariably connected with old age. The cause seems to be an excess of alkaline and earthy matter in the descending sap. I have often found carbonate of lime on the edges of the canker in apple trees; and ulmin, which contains fixed alkali, is abundant in the canker of the elm. The old age of a tree, in this respect, is faintly analogous to the old age of animals, in which the secretions of solid bony matter are always in excess, and the tendency to ossification great.

The common modes of attempting to cure the canker, are by cutting the edges of the bark, binding new bark upon it, or laying on a plaister of earth: but these methods, though they have been much extolled, probably do very little in producing a regeneration of the part. Perhaps the application of a weak acid to the canker might be of use; or where the tree is of great value, it may be watered occasionally with a very diluted acid. The alkaline and earthy nature of the morbid secretion warrants the trial; but circumstances that cannot be foreseen may occur to interfere with the success of the experiment.

Besides the diseases having their source in the constitution of the plant, or in the unfavourable operation of external elements, there are many others perhaps more injurious, depending upon the operations and powers of other living beings; and such are the most difficult to cure, and the most destructive to the labours of the husbandman.

Parasitical plants of different species which attach themselves to trees and shrubs, feed on their juices, destroy their health, and finally their life, abound in all climates; and, are, perhaps, the most formidable of the enemies of the superior and cultivated vegetable species.

The mildew, which has often occasioned great havock in our wheat crops, and which was particularly destructive in 1804, is a species of fungus, so small as to require glasses to render its form distinct, and rapidly propagated by its seeds.

This has been shewn by various botanists; and the subject has received a full illustration from the enlightened and elaborate researches of the President of the Royal Society.

The fungus rapidly spreads from stalk to stalk, fixes itself in the cells connected with the common tubes, and carries away and consumes that nourishment which should have been appropriated to the grain.

No remedy has as yet been discovered for this disease; but as the fungus increases by the diffusion of its seeds, great care should be taken that no mildewed straw is carried in the manure used for corn; and in the early crop, if mildew is observed upon any of the stalks of corn, they should be carefully removed and treated as weeds.*

The popular notion amongst farmers, that a barberry tree in the neighbourhood of a field of wheat often produces the mildew, deserves examination. This tree is frequently covered with a fungus, which if it should he shewn

* Until the researches of Philippar and Henslow, rust was usually attributed to fungi, named *Uredo rubigo*, and *U. linearis*, while mildew was ascribed to *Paccinia graminis*. Philippar considered the *U. linearis*, and *P. graminis* as identical; and more recently, Henslow has proved that all the three are but modifications of the same fungus; and hence, that rust and mildew are but different forms of the same disease (Journal of the Royal Agricultural Society of England, Vol. II). From the acknowledged efficacy of pickling, especially with sulphate of copper, in preventing the bunt fungus, he infers that it would be serviceable in preventing rust and mildew.

to be capable of degenerating into the wheat fungus, would offer an easy explanation of the effect. *

There is every reason to believe, from the researches of Sir Joseph Banks, that the smut in wheat is produced by a very small fungus, which fixes on the grain: the products that it affords by analysis are similar to those afforded by the puff-ball; and it is difficult to conceive, that without the agency of some organised structure, so complete a change should be effected in the constitution of the grain. †

The mistletoe and the ivy, the moss and the lichen, in fixing upon trees, uniformly injure their vegetative processes, though in very different degrees They are supported from the lateral sap vessels, and deprive the branches above of a part of their nourishment

The insect tribes are scarcely less injurious than the parasitical plants.

To enumerate all the animal destroyers and tyrants of the vegetable kingdom would be to give a catalogue of the greater number of the classes in zoology. Every species of plant almost is the peculiar resting place, or dominion of some insect tribe: and from the locust, the caterpillar, and snail, to the minute aphis, a wonderful variety of the inferior insects are nourished, and live by their ravages upon the vegetable world

I have already referred to the insect which feeds on the seed-leaf of the turnip

The Hessian fly, still more destructive to wheat, has in some seasons

* No satisfactory explanation of this widely-spread opinion, that the barberry-tree (*Berberis vulgaris*) is somehow connected with the production of mildew, has yet been given. Henslow, in the first of his valuable papers above referred to, was disposed to doubt the accuracy of the observation: in the second he says:—"As the fact of the berberry occasioning some sort of blight in wheat, but more especially mildew, has been forcibly brought before me from several quarters since my report was written, I am bound to suppose that there must occasionally exist some relation between the presence of this shrub and the occurrence of mildew in wheat At present I have met with no evidence which can explain the nature of this relation Is it that the soil, or that some ingredient partially present in the soil, may be favourable to the growth of the berberry, and at the same time deleterious to that of wheat: and thus reducing the latter plant to the sickly state suited to the attack of *Puccinia graminis?* Is it (what I presume no botanist will at present be prepared to admit) that one of the berberry-blights (*Æcidium berberidis*) can only be a different form of development belonging to the same species of fungus which produces the mildew?—or may we suppose that the disgusting odour of the flowers is due to some subtile emanation which sickens the wheat plant? I do not feel myself competent to offer even a suspicion of what may be the truth" In reference to the first of these questions, but without attaching much importance to the remark, it may be mentioned, that Sprengel repeatedly found phosphate of iron, in greater proportion than usual, in boggy and heathy soils that were remarkable for producing rust and mildew; and that in one case the soil when "removed to another locality, and made into an artificial soil of fifteen inches in depth," still produced rust in the wheat and barley sown in it, "whilst barley growing in the land surrounding this soil was not at all affected by the disease."

† Bunt, and to a great extent smut, may be prevented by steeping or pickling. Various solutions are used, but sulphate of copper, lime-water, or a very dilute solution of caustic potash are most esteemed. Hitherto it has not been customary to steep oats; partly because the value of the crop is less, and partly also on account of the greater quantity of seed sown per acre; but from the rapidity with which smut or dust-brand is increasing in many localities among the finer kinds of oats, there can be no doubt that it must soon be adopted.

threatened the United States with a famine. And the French government is* at this time issuing decrees with a view to occasion the destruction of the larvæ of the grasshopper.

In general, wet weather is most favourable to the propagation of mildew, funguses, rust, and the small parasitical vegetables; dry weather to the increase of the insect tribes Nature, amidst all her changes, is continually directing her resources towards the production and multiplication of life; and in the wise and grand economy of the whole system, even the agents that appear injurious to the hopes, and destructive to the comforts of man, are in fact ultimately connected with a more exalted state of his powers and his condition His industry is awakened, his activity kept alive, even by the defects of climates and season. By the accidents which interfere with his efforts, he is made to exert his talents, to look farther into futurity, and to consider the vegetable kingdom not as a secure and unalterable inheritance, spontaneously providing for his wants; but as a doubtful and insecure possession, to be preserved only by labour, and extended and perfected by ingenuity.

* January 1813.—D.

LECTURE VI.

OF MANURES OF VEGETABLE AND ANIMAL ORIGIN.—OF THE MANNER IN WHICH THEY BECOME THE NOURISHMENT OF THE PLANT.—OF FERMENTATION AND PUTREFACTION.—OF THE DIFFERENT SPECIES OF MANURES OF VEGETABLE ORIGIN; OF THE DIFFERENT SPECIES OF ANIMAL ORIGIN.—OF MIXED MANURES.—GENERAL PRINCIPLES WITH RESPECT TO THE USE AND APPLICATION OF SUCH MANURES.

THAT certain vegetable and animal substances introduced into the soil accelerate vegetation and increase the produce of crops, is a fact known since the earliest period of agriculture; but the manner in which manures act, the best modes of applying them, their relative value and durability, are still subjects of discussion. In this Lecture I shall endeavour to lay down some settled principles on these objects; they are capable of being materially elucidated by the recent discoveries in chemistry; and I need not dwell on their great importance to farmers.

The pores in the fibres of the roots of plants are so small, that it is with difficulty they can be discovered by the microscope; it is not therefore probable, that solid substances can pass into them from the soil. I tried an experiment on this subject; some impalpable powdered charcoal procured by washing gun-powder was placed in a phial containing pure water, in which a plant of peppermint was growing: the roots of the plant were pretty generally in contact with the charcoal. The experiment was made in the beginning of May, 1805; the growth of the plant was very vigorous during a fortnight, when it was taken out of the phial: the roots were cut through in different parts; but no carbonaceous matter could be discovered in them, nor were the smallest fibrils blackened by charcoal, though this must have been the case had the charcoal been absorbed in a solid form. *

* Although there can be no doubt that plants take up almost all their nourishment in the liquid or gaseous state, it is by no means certain that they are altogether incapable of taking up solid matter. Many experiments on infecting grain with the bunt and smut fungi appear to be explicable only on this supposition; thus when the seeds of sound wheat are rubbed with the black powder of the smut before being sown, the plants they produce are uniformly affected with smut; and this can scarcely be supposed to take place otherwise than by the absorption of the solid though extremely minute sporules of the fungus through the roots.

In speculating on the food of plants, it has been a common error to exaggerate the amount taken up in the liquid form, and overlook what is acquired in the state of gas and vapour. The experiments of Hales and others on the transpiration of plants shew that a great deal of water is absorbed by them, and if this is acquired from the soil through the roots, it follows, that a good deal of

No substance is more necessary to plants than carbonaceous matter; and if this cannot be introduced into the organs of plants except in a state of solution, there is every reason to suppose that other substances less essential will be in the same case.

I found by some experiments made in 1804, that plants introduced into strong fresh solutions of sugar, mucilage, tanning principle, jelly, and other substances died; but that plants lived in the same solutions after they had fermented. At that time, I supposed that fermentation was necessary to prepare the food of plants; but I have since found that the deleterious effect of the recent vegetable solutions was owing to their being too concentrated; in consequence of which the vegetable organs were probably clogged with solid matter, and the transpiration by the leaves prevented. In the beginning of June, in the next year, I used solutions of the same substances; but so much diluted, that there was only about $\frac{1}{100}$ part of solid vegetable or animal matter in the solutions. Plants of mint grew luxuriantly in all these solutions; but least so in that of the astringent matter. I watered some spots of grass in a garden with the different solutions separately, and a spot with common water: the grass watered with solutions of jelly, sugar, and mucilage, grew most vigorously; and that watered with the solution of the tanning principle grew better than that watered with common water.

I endeavoured to ascertain whether soluble vegetable substances passed in an unchanged state into the roots of plants, by comparing the products of the analysis of the roots of some plants of mint which had grown, some in common water, some in a solution of sugar. 120 grains of the roots of the mint which grew in the solution of sugar, afforded five grains of pale green extract, which had a sweetish taste, but which slightly coagulated by the action of alcohol. 120 grains of the roots of the mint which had grown in common water yielded three grains and a half of extract, which was of a deep olive colour; its taste was sweetish, but more astringent than that of the other extract, and it coagulated more copiously with alcohol.

These results, though not quite decisive, favour the opinion that soluble matters pass unaltered into the roots of plants; and the idea is confirmed by the circumstance that the radical fibres of plants made to grow in in-

carbonic acid and of saline and earthy matter will be taken up in solution. But that water is often acquired in the state of vapour is shewn by the fact, that unless in wet land and after heavy rains, the soil is always merely moist, and even when a portion of it is subjected to heavy pressure, water does not drop from it. Moisture is continually sublimed about in porous soils in contact with the roots of plants, and is thus presented in such a form as to carry with it only gaseous nourishment. In summer, although rain falls often, it is seldom in large quantities at a time. In the course of a rainy day, it sometimes falls to the extent of an inch in depth over the whole surface; but this would do no more than render a few inches of finely divided soil pasty; and although the roots were to absorb the water with great facility, it so soon sinks and is diffused through the whole mass, that the supply cannot long be supposed to take place by the absorption of water except as vapour; unless indeed, it could be shewn, that by the continued evaporation from the upper parts of the plant, the vapour in the soil is condensed on the spangioles. But dry weather often continues for weeks together, during which the crops continue to grow and thrive. Thus, it appears, that although the roots can readily take up water and whatever it holds in solution, and thus obtain a considerable portion of their food, especially the inorganic part, a great part of the supply of water and carbonic acid must be obtained in the gaseous state.

fusions of madder are tinged red; and it may be considered as almost proved by the fact, that substances which are even poisonous to vegetables are absorbed by them.* I introduced the roots of a primrose into a weak

* The question which the experiments detailed in the text were undertaken to determine is one of the greatest importance; and even now, considerable difference of opinion exists among the best authorities regarding it. Great as its theoretical importance is, its practical value is immensely greater; for if vegetable proximate principles, such as gum, sugar, starch, and humus, are directly absorbed by plants, and constitute their proper food, it will require a theory and treatment of manures very different from what would be proper if carbonic acid, water, ammonia, and the earthy and saline matters constitute their true food. In the case of plants growing in soils containing little or no organic matter, and in those that live chiefly by absorption from the air, there is no doubt that the latter explanation applies; and this constitutes a strong argument for considering that others living in highly organic soils, and obtaining a great part of their food through the roots, are nourished similarly—that is to say, that the carbon afforded by the soil is supplied as carbonic acid, and the nitrogen as ammonia.

Liebig contends that starch, sugar, gum, and gluten, when they nourish plants, do so only in peculiar instances; thus, they exist in the seed as nourishment for the young plant till the development of its organs which procure nourishment from the soil and the air; and they are formed in autumn, and laid up in store in the wood, to be exhausted by the growing parts in the succeeding spring; but they are not at all of the kind of nourishment taken up by the roots. He says:—"If we could introduce into a tree woody fibre in a state of solution, it would be the same thing as placing a potato plant to vegetate in a paste of starch. The office of the leaves is to form starch, woody fibre, and sugar; consequently, if we convey these substances through the roots, the vital functions of the leaves must cease, and if the process of assimilation cannot take another form, the plant must die." And again:—"In whatever form, therefore, we supply plants with those substances which are the products of their own action, in no instance do they appear to have any effect upon their growth, or to replace what they have lost. Sugar, gum, and starch, are not food for plants, and the same may be said of humic acid, which is so closely allied to them in composition." In speaking of the evolution of oxygen by plants, he says:—"No matter can be considered as nutritious, or as necessary to the growth of plants, which possesses a composition either similar to or identical with theirs, and the assimilation of which, therefore, could take place without exercising this function. The reverse is the case in the nutrition of animals. Hence, such substances as sugar, starch, and gum, which are themselves products of plants cannot be adapted for assimilation. And this is rendered certain by the experiments of vegetable physiologists, who have shewn that aqueous solutions of these bodies are imbibed by the roots of plants, and carried to all parts of their structure, but are not assimilated, they cannot therefore be employed in their nutrition. We could scarcely conceive a form more convenient for assimilation than that of gum, starch, or sugar, for they all contain the elements of woody fibre, and nearly in the same proportions." And further:—"Substances, such as sugar, starch, &c., which contain carbon and the elements of water, are products of the life of plants which live only whilst they generate them. The same may be said of humus, for it can be formed in plants like the former substances. Smithson, Jameson, and Thomson, found that the black excretions of unhealthy elms, oaks, and horse-chestnuts, consisted of humic acid in combination with alkalies. Berzelius detected similar products in the bark of most trees. Now, can it be supposed that the diseased organs of a plant possess the power of generating the matter to which its substance and vigour are ascribed.?"

In the experiments detailed in the text, Davy's first conjecture, that fermentation was necessary to prepare the food of plants," is, no doubt, correct. When fermentation took place carbonic acid was produced, and upon it the plants fed.

solution of oxide of iron in vinegar, and suffered it to remain in it till the leaves became yellow; the roots were then carefully washed in distilled water, bruised, and boiled in a small quantity of the same fluid: the decoction of them passed through a filter was examined by the test of infusion of nut-galls; the decoction gained a strong tint of purple, which proves that solution of iron had been taken up by the vessels or pores in the roots.

Vegetable and animal substances, as is shewn by universal experience, are consumed in vegetation; and they can only nourish the plant by affording solid matters capable of being dissolved by water, or gaseous

If any of the proximate principles in solution were taken up, they could not prove nutritive, and behoved either to be at length thrown out with the excretions, or to remain inert in the plant. With respect to the more diluted solutions, it may be conjectured, that the greater quantity of absorbed oxygen present contributed to a change in the organic bodies contained in the solution, whereby carbonic acid was slowly and imperceptibly evolved and rendered available for the growing plants.

Many physiologists maintain that plants derive a great part of their carbon from humous matter in the soil, and that they absorb it in solution in the form of humates of lime and ammonia. Liebig while he admits that organic matter in the soil is useful in supplying carbon, denies that it is in the form of humates that it is taken up. Organic matter in soils to which air has access is continually undergoing decay, and carbonic acid thus formed constitutes the carbonaceous nutritive matter supplied by the soil. Liebig's principal arguments against the common theory may be thus condensed. 1st, The humic acid of chemists does not occur in appreciable quantity in fertile soils; it is formed in the course of the chemical processes had recourse to to procure it. If humates existed in the soil and constituted the food of plants, they would communicate a brown tint, and be readily detected in the water of springs, brooks, and rivers, but they are not so; neither do they occur in sea-water, hence, it must be from carbonic acid that the immense crops of algæ that grow on the bottom and shores of the sea derive their carbon. 2d, The humates are so little soluble, that it can be shewn, that all the rain that falls during the growth of common crops is incapable, even if it were all to be saturated with humates, and to pass through the plants, of affording a tithe of the carbon they require. 3d, There was no original humus, and hence it is not absolutely essential. 4th, Many plants have but a point of attachment in the soil, and live almost entirely by absorption from the air. 5th, Neither in cultivated land that is regularly manured, nor in forest and meadow lands that are not, does the humus decrease; in the latter cases, indeed, it increases. Boussingault shows in the case of the five-course rotation already referred to, that the carbon contained by the crops exceeded that contained by the manure, by 4745·5 kilogrammes per hectare = 4233·9 lbs. per imperial acre. The carbon, therefore, must, to this extent at least, have been derived from the air; and at the close of the rotation the humus had not decreased. Hence, it may be inferred, that the carbon derived from the organic matter in the soil was also taken up in the form of carbonic acid.

Of recent attempts to settle the question by direct experiment, those of Saussure have attracted most attention. He endeavoured to shew that soluble humates are taken up and assimilated by causing plants of the bean and polygonum to grow in a decoction of mould in bicarbonate of potash. Liebig has criticised these experiments, and shewn, that they are inexact and inconclusive; and that the results are capable of a satisfactory explanation only on the principles they were intended to refute.

On the whole then, it appears that there is no sufficient reason for holding that soluble humates form any appreciable or important part of the food of plants, however useful humus may be, both as a textural constituent of soils, and as affording carbonic acid by gradual decay.

substances capable of being absorbed by the fluids in the leaves of vegetables; but such parts of them as are rendered gaseous, and that pass into the atmosphere, must produce a comparatively small effect, for gases soon become diffused through the mass of the surrounding air. The great object in the application of manure should be to make it afford as much soluble matter as possible to the roots of the plant; and that in a slow and gradual manner, so that it may be entirely consumed in forming the sap or organised parts of the plant.

Mucilaginous, gelatinous, saccharine, oily, and extractive fluids, and solution of carbonic acid in water, are substances that in their unchanged states contain almost all the principles necessary for the life of plants; but there are few cases in which they can be applied as manures in their pure forms; and vegetable manures, in general, contain a great excess of fibrous and insoluble matter, which must undergo chemical changes before they can become the food of plants.

It will be proper to take a scientific view of the nature of these changes; of the causes which occasion them, and which accelerate or retard them; and of the products they afford.

If any fresh vegetable matter which contains sugar, mucilage, starch, or other of the vegetable compounds, soluble in water, be moistened and exposed to air, at a temperature from 55° to 80°, oxygen will soon be absorbed, and carbonic acid formed; heat will be produced, and elastic fluids, principally carbonic acid, gaseous oxide of carbon, and hydro-carbonate will be evolved; a dark coloured liquid of a slightly sour or bitter taste will likewise be formed; and if the process be suffered to continue for a time sufficiently long, nothing solid will remain, except earthy and saline matter, coloured black by charcoal.

The dark coloured fluid formed in the fermentation always contains acetic acid: and when albumen or gluten exists in the vegetable substance, it likewise contains volatile alkali.

In proportion as there is more gluten, albumen, or matters soluble in water in the vegetable substances exposed to fermentation, so in proportion, all other circumstances being equal, will the process be more rapid. Pure woody fibre alone undergoes a change very slowly;* but its texture

* It has already been shewn that humus and the organic part of manures, as they decay, nourish plants by supplying carbonic acid. Woody tissue constitutes the principal part of many of the manures in common use. Thus of clover, peas, tares, and other plants ploughed in green, as well as of the roots of grasses turned down when lea is broken up, it forms the principal part. The excrements of cattle and horses fed on straw, hay, &c., contain a large quantity of woody tissue, not to mention the still larger quantity contained by the straw used as litter, and trodden down and mixed with the excrements in the court-yards. Pure woody tissue is capable of decay, but the decomposition is greatly hastened by the presence of azotised bodies. Even the wood of forest trees contains incrusting matter, of which nitrogen is a constituent, and which hastens its decay; and the woody tissue in farm-yard manure is mixed with a much larger proportion of azotised matter. The decay of wood has been fully discussed by Liebig. He shews that the mode of decomposition varies according to the more or less free admission of atmospheric air. In soils, especially open soils, these two conditions—the presence of moisture, and the free admission of air, greatly facilitate the process; and the presence of alkalies and alkaline earths also promotes it by favouring the absorption of oxygen. From the analysis of wood in a sound state, as well as in various stages of decay, Liebig infers that the oxygen of the air unites with the hydrogen of the tissue producing water, while the carbonic acid evolved is formed from the elements of the wood.

is broken down, and it is easily resolved into new elements when mixed with substances more liable to change, containing more oxygen and hydrogen. Volatile and fixed oils, resins and wax, are more susceptible of change than woody fibre when exposed to air and water; but much less liable than the other vegetable compounds; and even the most inflammable substances by the absorption of oxygen, become gradually soluble in water.

Animal matters in general are more liable to decompose than vegetable substances; oxygen is absorbed, and carbonic acid and ammonia formed in the process of their putrefaction. They produce fœtid compound elastic fluids, and likewise azote: they afford dark coloured acid and oily fluids, and leave a residuum of salts and earths mixed with carbonaceous matter.

The principal substances which constitute the different parts of animals, or which are found in their blood, their secretions, or their excrements, are gelatine, fibrine, mucus, fatty, or oily matter, albumen, urea, uric acid, and different acid, saline, and earthy matters.

Of these, *gelatine* is the substance which when combined with water forms jelly. It is very liable to putrefaction. According to MM. Gay Lussac and Thenard, it is composed of

47·88 of Carbon.
27·207 — Oxygen.
7·914 — Hydrogen.
16·998 — Azote.

These proportions cannot be considered as definite, for they do not bear to each other the ratios of any simple multiples of the number representing the elements;* the case seems to be the same with other animal compounds: and even in vegetable substances, in general, as appears from the statements given in the Third Lecture, the proportions are far from having the same simple relations as in the binary compounds capable of being made artificially, such as acids, alkalies, oxides, and in salts.

He shews that for every two equivalents of hydrogen which are oxidised, one equivalent of carbonic acid is set free. Were this action to go on, the result would be that after the conversion of all the hydrogen into water, and after the escape of all the oxygen as carbonic acid, a considerable portion of the carbon would remain in an uncombined state:—"But," says he, "this final result is never attained in the decay of wood under common circumstances; and for this reason, that with the increase of the proportion of carbon in the residual humus, as in all decompositions of this kind, its attraction for the hydrogen, which still remains in combination, also increases, until at length the affinity of oxygen for the hydrogen is equalled by that of the carbon for the same element."

From these considerations various practical conclusions follow; thus, That when woody tissue, and substances containing a large proportion of this substance in their composition, are used as manures, they should be mixed with organic matter containing nitrogen to facilitate decay. That the admission of air being a condition essential to decay, clay soils may be made more fertile by admixture of sand or gravel, to render the humus they contain, or the manure applied to them more readily available to plants; while sandy and gravelly soils that have too free access of air are improved by dressing with clay or clay-marl. That lime and alkaline matters possess a value independent of what is due to their being directly required as inorganic constituents of plants. And that peat, saw-dust, spent bark, and similar substances, when properly mixed in compost, constitute useful manures and ought not to be allowed to run to waste.

* According to Scherer gelatine may be represented by the formula $C_{48}\ H_{41}\ N_{7\frac{1}{2}}\ O_{15}$.

Fibrine constitutes the bases of the muscular fibre of animals, and a similar substance may be obtained from recent fluid blood; by stirring it with a stick the fibrine will adhere to the stick. It is not soluble in water; but by the action of acids, as Mr Hatchett has shewn, it becomes soluble, and analogous to gelatine. It is less disposed to putrefy than gelatine. According to MM. Gay Lussac and Thenard, 100 parts of fibrine contain

Of Carbon, . . .	53·360
— Oxygen, . . .	19·685
— Hydrogen, . . .	7·021
— Azote, . . .	19·934 *

Mucus is very analogous to vegetable *gum* in its characters; and as Dr. Bostock has stated, it may be obtained by evaporating saliva. No experiments have been made upon its analysis; but it is probably similar to gum in composition. It is capable of undergoing putrefaction, but less rapidly than fibrine.

Animal fat and *oils* have not been accurately analysed;† but there is great reason to suppose that their composition is analogous to that of similar substances from the vegetable kingdom.

Albumen has been already referred to, and its analysis stated in the Third Lecture. ‡

Urea may be obtained by the evaporation of human urine, till it is of the consistence of a syrup; and the action of alcohol on the crystalline substance which forms when the evaporated matter cools. In this way a solution of urea in alcohol is procured, and the alcohol may be separated from the urea by heat. Urea is very soluble in water, and is precipitated from water by diluted nitric acid in the form of bright pearl-coloured crystals; this property distinguishes it from all other animal substances.

According to Fourcroy and Vauquelin, 100 parts of urea when distilled yield

92·027 parts of Carbonate of Ammonia.
4·608 Carburetted Hydrogen gas.
3·225 of Charcoal. §

Urea, particularly when mixed with albumen or gelatine, readily undergoes putrefaction.

Uric Acid, as has been shewn by Dr. Eagan, may be obtained from human urine by pouring an acid into it; and it often falls down from urine in the form of brick-coloured crystals. It consists of carbon, hydrogen, oxygen, and azote; but their proportions have not yet been determined. ‖ Uric acid is one of the animal substances least liable to undergo the process of putrefaction.

According to the different proportions of these principles in animal compounds, so are the changes they undergo different. When there is

* For the formula of fibrine, see note, page 48.

† According to Chevreul, mutton fat is composed of

Carbon,	78·996
Hydrogen,	11·700
Oxygen,	9·304

which corresponds nearly with the formula, C_{11} H_{10} O.

‡ See note, page 48.

§ Urea is represented by the formula C_2 H_4 N_2 O_2. A better process for its preparation is now known, but it is unnecessary here to give it.

‖ Uric acid is represented by the formula C_{10} H_4 N_4 O_6.

much saline or earthy matter mixed or combined with them, the progress of their decomposition is less rapid than when they are principally composed of fibrine, albumen, gelatine, or urea.

The ammonia given off from animal compounds in putrefaction may be conceived to be formed at the time of their decomposition by the combination of hydrogen and azote; except this matter, the other products of putrefaction are analogous to those afforded by the fermentation of vegetable substances; and the soluble substances formed abound in the elements, which are the constituent parts of vegetables, in carbon, hydrogen, and oxygen.

Whenever manures consist principally of matter soluble in water, it is evident that their fermentation or putrefaction should be prevented as much as possible; and the only cases in which these processes can be useful, are when the manure consists principally of vegetable or animal fibre. The circumstances necessary for the putrefaction of animal substances are similar to those required for the fermentation of vegetable substances; a temperature above the freezing point, the presence of water, and the presence of oxygen, at least in the first stage of the process.

To prevent manures from decomposing, they should be preserved dry, defended from the contact of air, and kept as cool as possible.

Salt and alcohol appear to owe their powers of preserving animal and vegetable substances to their attraction for water, by which they prevent its decomposing action, and likewise to their excluding air. The use of ice in preserving animal substances is owing to its keeping their temperature low. The efficacy of M. Appert's method of preserving animal and vegetable substances, an account of which has been lately published, entirely depends upon the exclusion of air. This method is by filling a vessel of tin plate or glass with the meat or vegetables; soldering or cementing the top so as to render the vessel air-tight; and then keeping it half immersed in a vessel of boiling water for a sufficient time to render the meat or vegetables proper for food. In this last process it is probable that the small quantity of oxygen remaining in the vessel is absorbed: for on opening a tinned iron cannister which had been filled with raw beef, and exposed to hot water the day before, I found that the minute quantity of elastic fluid which could be procured from it, was a mixture of carbonic acid gas and azote.

Where meat or vegetable food is to be preserved on a large scale, for the use of the navy or army for instance, I am inclined to believe, that by forcibly throwing a quantity of carbonic acid, hydrogen, or azote into the vessel, by means of a compressing pump, similar to that used for making artificial Seltzer water, any change in the substance would be more effectually prevented. No elastic fluid in this case would have room to form by the decomposition of the meat; and the tightness and strength of the vessel would be proved by the process. No putrefaction or fermentation can go on without the generation of elastic fluid; and pressure would probably act with as much efficacy as cold in the preservation of animal or vegetable food.

As different manures contain different proportions of the elements necessary to vegetation, so they require a different treatment to enable them to produce their full effects in agriculture. I shall therefore describe in detail the properties and nature of the manures in common use, and give some general views respecting the best modes of preserving and applying them.

All *green succulent plants* contain saccharine or mucilaginous matter

with woody fibre, and readily ferment. They cannot, therefore, if intended for manure, be used too soon after their death.

When *green crops* are to be employed for enriching a soil, they should be ploughed in, if it be possible, when in flower, or at the time the flower is beginning to appear, for it is at this period that they contain the largest quantity of easily soluble matter, and that their leaves are most active in forming nutritive matter. Green crops, pond weeds, the paring of hedges or ditches, or any kind of fresh vegetable matter, requires no preparation to fit them for manure. The decomposition slowly proeeeds beneath the soil; the soluble matters are gradually dissolved, and the slight fermentation that goes on checked by the want of a free communication of air, tends to render the woody fibre soluble without occasioning the rapid dissipation of elastic matter. *

* This very important means of enriching the soil has been but too little attended to in Britain, particularly in Scotland. The chief causes of its neglect are,—1st, The want of a due appreciation of its value; 2d, The lateness of the harvest, and consequent slowness of growth between the time of sowing the plants and that of ploughing them in; 3d, Its being inadmissible except at particular points of the rotations in common use; and, 4th, The carrying out to an unwarrantable extent the principle, that green vegetable substances, to be profitably employed as manures, ought to be, in the first place, used as food for animals.

It will readily be granted, that the amount of produce that can, in any shape, be exported from a farm, without deteriorating the land, is a portion corresponding to what the crops have drawn from the air, above what was contained by the manure. Inorganic substances are derived exclusively from the soil, but as crops contain a certain proportion of these, the supply must be maintained either by decomposition of mineral matter in the soil—and even in the best soils this is but a limited source—or by manures obtained from sources foreign to the farm. It follows then, that if plants capable of drawing largely on the air are grown, and ploughed in at the time they contain most of the matter so derived, and in a condition favourable to steady and complete decay, that all that could be exported is gain, and is laid up in the soil, to enable it to minister to other crops of more profitable kinds. The plants which form the most valuable food for animals are almost all incapable of being raised on very poor soils, and they draw most largely on the soil for support; there are, however, others less fitted for feeding animals, that draw largely on the air, and are capable of growing on poor soils: it is these that are most appropriately employed for green manuring. In selecting plants for this purpose, care should be taken that they are rapid growers, nourished chiefly at the expense of the air, capable of autumnal growth, and that they are hardy and suitable to the soil and climate.

Green plants are greatly superior to dry ones as manure, in being capable of speedier and more complete decomposition. Dry vegetable matter introduced into the soil decomposes slowly, because, in drying, changes have already taken place in the sap that render it less prone to decomposition even in the presence of air and moisture; hence, straw requires to be mixed with other decomposing substances, such as animal excrements, and turned over in a heap, before it becomes fit for the purpose of profitable manuring. But this is not the case with green succulent plants; their sap contains albumen, and other azotised principles, highly susceptible of decomposition, and which readily induce decay on the woody and cellular tissues of the plants, particularly in the green and succulent state in which they exist when the plant is coming into flower. Green plants, then, being very susceptible of decay, it is obviously of importance to plough them in to such a depth, as will prevent the drying action of the air, yet not so deeply but that the amount of air necessary for the process of decay can obtain access. Three or four inches will in general suffice for this purpose.

Different plants have been recommended and used for the purpose of green-

When old pastures are broken up and made arable, not only has the soil been enriched by the death and slow decay of the plants which have left soluble matters in the soil; but the leaves and roots of the grasses living at the time and occupying so large a part of the surface, afford

manuring, such as peas, vetches, aftermath clover, buck-wheat, lupine, rye, spurrey, rape, &c.; each, perhaps, deserving preference in particular localities, and under circumstances of soil, climate, and rotation, of which practical farmers will have little difficulty in judging.

It is worthy of the consideration of those who farm stiff soils, where the naked fallow is indispensable, whether, in favourable seasons, when the tillage and clearing of weeds have been got through early, it would not be possible to raise a crop of some of the before mentioned plants, in time to be ploughed in, before the season of sowing winter wheat. It is not meant that this could supersede the common manuring; but it is certainly one of the expedients that ought to be had recourse to, especially on stiff clay farms, where the rotation is short, and where, from the want of fallow-crops, the sources of manure are much curtailed. It may be remarked as a further inducement, that wheat is one of the crops most benefitted by this kind of manuring.

In this country almost the only case where green-plants, or rather parts of plants, are systematically ploughed in, is when grass or pasture is broken up. The breaking up of lea is undoubtedly a case of green manuring, although most farmers have not been accustomed to view it in this light. Under the head of rotation of crops, it will be shewn what reason there is to believe that while the land is in lea, the soil becomes enriched by the excretions of the grasses and clovers. Apart from this, however, any one may readily satisfy himself by carefully examining a piece of a furrow-slice of lea, that the roots and lower parts of the stems of the grasses and clovers bear a considerable proportion, especially in dry weight, to the part that is depastured or mown; and being ploughed down in a green state, and undergoing steady and complete decay in the soil, they afford large supplies of nourishment to the succeeding grain crop. From these considerations it follows, that to obtain the full benefit from breaking up lea, it should be done as soon after harvest as possible, while the herbage is still green and juicy; and that there is no economy in depasturing too closely.

In lands that admit of fallow-crops, such as turnips, a method of green manuring is beginning to be adopted in some localities, that promises to be attended with great success, and deserves to be more generally known; it is the ploughing in of the tops and tails of the turnips. When winter wheat is to succeed turnips, there is a necessity for clearing the ground, and then the bulbs only are stored, the tops and tails being ploughed in. When it is to be a spring crop, it is better to allow the turnips to remain longer in the ground, both to attain their full growth, and for preservation; but even in that case, it is necessary to have a supply stored for hard frosts and very wet weather; and there can be no doubt, that the swedes and yellows left for spring consumption, ought to be stored before the first indications of spring growth. It is generally admitted that when turnips are stored, the tops and tails should be left in the field; but it is here maintained, that in all cases they should be so, because, it is only in autumn that any considerable portion of the leaves are eaten by stock. After November cattle generally refuse the leaves, and they are of course left to wither in the air, or are thrown to the dunghill; in either case, almost the only portion of them that reaches the field is the inorganic part; the organic portion being wasted. In the localities where ploughing in the tops and tails has been adopted, it is done to the whole crop—what is drawn for immediate use, as well as what is stored. The turnips are of course grown in drills; as each turnip is drawn, the top and tail are struck off with a curved knife or fragment of a sickle, and laid evenly in the furrow between the drills. When the bulbs are carted off, the tops and tails are the same day covered in by means of the plough. The grain grown after this dressing has always been found to be of fine quality,

saccharine, mucilaginous, and extractive matters, which become immediately the food of the crop,* and the gradual decomposition affords a supply for successive years.

Rape cake, which is used with great success as a manure, contains a

and not liable to be lodged. With the view of ascertaining the comparative value of this method, I have several times had the produce weighed from two parts of the same field, the one treated as above, the other eaten off by sheep; and have found the balance both in quantity and weight of grain, in favour of the ploughing in of the tops and tails. Unless where wheat is to succeed turnips on a soil so light and friable as to demand the treading of the sheep for textural improvement, this method of green-manuring deserves a trial. The only peculiarity of subsequent treatment that needs to be noticed, is, that the braird of the grain crop requires more rolling than usual, and with a heavier roller. From many trials made in the months of November and December 1842, I find, that the ratio, by weight, of the tops and tails to the bulbs, is, on an average, as 1 to 3·3. But 25 tons of bulbs, per imperial acre, is considered a good crop; and this would give 7 tons 11 cwt., 2 qrs. of tops and tails, which should produce as great an effect on the succeeding crops as a dose of 10 tons of well-prepared farm-yard manure. Of turnip leaves no accurate analysis, so far as I am aware, has yet been published; but they are known to contain a considerable proportion of saline and earthy matter, not to mention the purely organic part, capable of nourishing the succeeding crops of the rotation. If Sprengel's estimate may be relied on, namely, that green turnip leaves contain 1·8 per cent. of inorganic matter, the quantity above specified would contain 303½ lbs. Now when the effect of a much smaller dose of mixed saline manures is considered, it will not appear strange that so much stress has been laid on ploughing in green turnip tops, as a means of enriching the soil and securing good after-crops. It may also be noticed here, that when turnips are eaten off by sheep, it is important to have the droppings and cups ploughed in the moment the nets are removed; unless where the land is already very rich, and the crops more than ordinarily liable to be attacked by wire-worm and other insects.

The remarks just made on green-manuring with turnip tops do not apply to potato-halm, that being withered and dried to a considerable extent by the time the tubers are ripe. Still, however, from the large quantity of potash contained by potato tops, it is of great importance that they be left on the field, and as equally spread over it as possible. A practice by no means to be commended, is every where to be seen in Scotland—it is this: after collecting the potatoes which have been turned up by the plough, the rest are brought to the surface by the harrows, which at the same time collect the tops; these are gathered into heaps and used to cover the potatoes in the pits. Now it is much better to leave them, for they are rich in the very constituents required by the succeeding grain and grass; and these crops can derive no benefit from the tops, even if they were carried to the compost heap after doing duty in the potato-pits. And again, straw, from being quite dry, and a bad conductor of heat, forms a better covering for the pits, and is at the same time less valuable as a manure.

Weeds and other green vegetable matter that are from time to time cut down and collected on a farm, might in like manner be ploughed in; but being obtained irregularly, and in but small quantities at a time, the compost heap is their more appropriate destination. It greatly facilitates the decomposition of these weeds, to have them cut by a chaff-cutter before being mixed with the earth in the heap. The parings of hedges and ditches it is never advisable to plough in green, from the amount of seeds of weeds that too frequently accompanies them; and for the same reason, they should be thoroughly decomposed before they are used as manure.

* It has been shewn (page 200, note,) that "saccharine, mucilaginous, and extractive matters," do not, *as such*, constitute the food of plants; but that as they decay, they afford carbonic acid, which is the true source of the carbon of plants.

large quantity of mucilage, some albuminous matter, and a small quantity of oil. This manure should be used recent, and kept as dry as possible before it is applied It forms an excellent dressing for turnip crops; and is most economically applied by being thrown into the soil at the same time with the seed Whoever wishes to see this practice in its highest degree of perfection, should attend Mr. Coke's annual sheep-shearing at Holkham *

Malt dust consists chiefly of the infant radicle separated from the grain. I have never made any experiment upon this manure; but there is great reason to suppose it must contain saccharine matter; and this will account for its powerful effects. Like rape cake it should be used as dry as possible, and its fermentation prevented †

* Rape-cake contains all the constituents of the seeds except the oil, and indeed of that, a small and variable quantity remains The rape-cake of commerce is sometimes produced from the rape (*Brassica napus*), but more frequently from the colza (*Brassica campestris*), which affords more oil, and of better quality Similar cakes are obtained when the seeds of other plants are used to afford oil such as hemp and linseed, arachis, madia, poppyseed, &c. The chief value of these cakes as manures consists in the proportionally large quantity of nitrogen they contain, whereby when placed in proper circumstances they readily undergo decomposition, and induce decay in other organic bodies less liable to it Among many other manures, Boussingault and Payen have analysed four varieties of cake (see translation of their table in the appendix to this lecture) Colza-cake in its normal state contains 4 92 per cent of nitrogen, while well-made farm-yard manure contains but 4 per cent; hence, so far as this element is concerned 8 13 parts of colza-cake should manure as much land as 100 parts of farm-yard manure; or if we compare the usual green-crop dose for an acre, 20 tons of farm-yard manure would be equivalent to 1 ton 3 cwt, 2 qrs 10¼ lbs of colza-cake. I have met with no accurate analysis of the inorganic part of these cakes

Rape-dust, that is, rape or colza-cake bruised or ground to powder, has been a good deal employed in this country as a manure for turnips as well as for grass and grain crops The usual dose for turnips is from 10 to 15 cwt, and a less dose is generally given for grass and grain crops. It requires merely to be sown and harrowed in with the seed, or it may be sown on grass or braird of grain without harrowing. It is said to succeed best on rather stiff soils, and in wet seasons, moisture being necessary for its decomposition In the Netherlands it is used to strengthen the urine and liquid manures; and in Scotland I have known it added to neutralised urine with remarkable success. When the farmer has a quantity of peat or inert vegetable matter in compost, in which he desires to set up decay as speedily as possible, he will find admixture of rape-dust to be one of the best and most economical ways of effecting it

† Malt-dust is a useful manure, but less efficient than rape-dust The general dose is from five to seven quarters per acre In consequence of its bulk, it is not so well adapted for transport as many other manures, such as guano, or very fine bone-dust, prepared with sulphuric acid; neither can its effects be so certainly relied on In the neighbourhood of large breweries it is a good deal used, though in small establishments it is too often thrown away It may be proper here to notice, that about breweries a great deal of matter, useful as manure, is generally allowed to run to waste, that might be collected by simple arrangements, and at trifling expense When the infusion of malt is boiled, a sediment separates and is left behind when the clear part is run off Another sediment consists of the refuse or insoluble ferment which is deposited in the vessels in which the process of fermentation is carried on Both these sediments are rich in nitrogen, and answer admirably in compost heaps for inducing decomposition on dry leaves, peat, sawdust, &c. I have found it very useful to add to these compost heaps, at the first turning, a small quantity of the prepared

Linseed cake is too valuable as a food for cattle to be much employed as a manure; the analysis of linseed was referred to in the Third Lecture. *The water* in which *flax* and *hemp* are steeped for the purpose of obtaining the pure vegetable fibre, has considerable fertilizing powers. It appears to contain a substance analogous to albumen, and likewise much vegetable extractive matter. It putrefies very readily. A certain degree of fermentation is absolutely necessary to obtain the flax and hemp in a proper state; the water to which they have been exposed should therefore be used as a manure as soon as the vegetable fibre is removed from it.*

Sea-weeds, consisting of different species of fuci, algæ, and confervæ, are much used as a manure on the sea coasts of Britain and Ireland. By digesting the common fucus, which is the sea weed usually most abundant on the coast, in boiling water, I obtained from it one-eighth of a gelatinous substance which had characters similar to mucilage. A quantity distilled gave nearly four-fifths of its weight of water, but no ammonia; the water had an empyreumatic and slightly sour taste; the ashes contained sea salt, carbonate of soda, and carbonaceous matter. The gaseous matter afforded was small in quantity, principally carbonic acid and gaseous oxide of carbon, with a little hydro-carbonate. This manure is transient in its effects, and does not last for more than a single crop, which is easily accounted for from the large quantity of water, or the elements of water, it contains. It decays without producing heat when exposed to the atmosphere, and seems as it were to melt down and dissolve away. I have seen a large heap entirely destroyed in less than two years, nothing remaining but a little black fibrous matter.

I suffered some of the firmest part of a fucus to remain in a close jar containing atmospheric air for a fortnight; in this time it had become very much shrivelled; the sides of the jar were lined with dew. The air examined was found to have lost oxygen, and contained carbonic acid gas.

Sea-weed is sometimes suffered to ferment before it is used; but this process seems wholly unnecessary, for there is no fibrous matter rendered soluble in the process, and a part of the manure is lost.

The best farmers in the west of England use it as fresh as it can be procured; and the practical results of this mode of applying it are exactly conformable to the theory of its operation. The carbonic acid formed by its incipient fermentation must be partly dissolved by the water set free in the same process; and thus become capable of absorption by the roots of plants.

The effects of the sea-weed as manure must principally depend upon this carbonic acid, and upon the soluble mucilage the weed contains; and I found that some fucus which had fermented so as to have lost about half its weight, afforded less than $\frac{1}{12}$ of mucilaginous matter; from which it may be fairly concluded that some of this substance is destroyed in fermentation.†

prepared bone-dust, to be afterwards described, in the proportion of a bushel of the dust to a ton of compost.

* I have never examined the water in which flax had been steeped, but from its very disagreeable smell, and its burning up the grass on the spots where the flax is laid on being removed from the steep, it is probable that it contains ammonia. When this water is allowed to escape into streams, it as effectually destroys the fish near the spot as lime water would do.

† From the experiment mentioned in the text, it might be inferred that sea

Dry straw of wheat, oats, barley, beans and peas, and spoiled hay, or any other similar kind of dry vegetable matter is, in all cases, useful manure. In general, such substances are made to ferment before they are employed, though it may be doubted whether the practice should be indiscriminately adopted.

weed contains no nitrogen In decomposing, it certainly emits a very different smell from that given out by terrestrial plants known to contain nitrogen; recent analyses, however, have shewn that it does contain this element. In Boussingault and Payen's table in the appendix to this lecture, there will be found two analyses of the *Fucus digitatus*, and two of the *F. saccharinus*, from which it appears that the latter, even when fresh from the sea, contains more nitrogen than well-made farm-yard manure Fresh sea-weeds contain a large percentage of water; and they are formed of cellular tissue, which undergoes decomposition more readily than woody tissue. Hence, when exposed to the air, mixed in compost, or ploughed in after the manner of green manures, sea-weeds speedily decompose, and produce a powerful effect on vegetation, although their influence does not, in general, extend beyond a single season. Much of the fertilising power of sea-weeds is no doubt due to the large quantity of alkaline and earthy salts they contain. The proportion of alkaline salts varies considerably in different species; so much so, that kelp-burners use chiefly the firm coriaceous species that grow about and under low water-mark; such as the *Fucus digitatus*, *F. nodosus*, *F. saccharinus*, &c, while they reject, or account of much less value, the *Fucus serratus*, *F. vesiculosus*, *F. canaliculatus* and others that grow in shallower water. In the absence of accurate analyses of the inorganic part of these plants, it is not possible to speak with precision of their relative values; but, on the shores of the north of Scotland, I have uniformly found that the most observant farmers, who have had much experience in the use of sea-weeds as a manure, manifest the same preferences as kelp-burners

Sea-weed is applicable to all the crops of ordinary culture; but is perhaps most frequently used as a dressing to lea, particularly what is to be broken up for white-crop. When applied on the grass in summer or autumn it rapidly disappears, producing a rich covering of grass of a deep green colour, and the succeeding grain crop is thereby much improved. Sea-weed is occasionally mixed in compost with earth and peat, particularly when it is wished to get a compost heap ready for use in a short time. It is also frequently mixed with farm-yard manure, to hasten the decomposition of the straw in the portion that is made so late in spring, that it would not, in the ordinary way, be got sufficiently fermented by the time of turnip-sowing. For this purpose, the sea-weed is spread upon the top of the dung-hill, along with the fresh portion of the dung, and is turned along with that portion into the bottom of the heap, about a fortnight before the time it is to be applied to the land.

Some farmers, and especially the market gardeners in the north of Scotland, prefer sea-weed to any other manure, for growing cabbages, greens, and other vegetables that are apt to become rank and bitter when grown after farm-yard manure.

As the supply of sea-weed cast ashore after storms, comes very irregularly, being dependent on winds, tides, and currents, on coasts favourable to its growth; it might be advantageously cut and collected, as was common enough, when the manufacture of kelp was carried on. It was found that the weed might be cut every two years, and indeed most of the weeds detach themselves in about that time; hence, the advantage of cutting is to ensure them against being carried off the coast on which they grow. From the large percentage of water it contains, the carriage of sea-weed is heavy, particularly when the coast is rugged, and the access to the beach difficult In such a case, the carriage might be much lightened by spreading the recent sea-weed on the beach, above water-mark, till it is half dried. In this state it is preferred in some localities; when, however, it is to be used as a top-dressing, or to produce rapid fermentation as above described, it cannot be applied too fresh.

From 400 grains of dry barley straw I obtained eight grains of matter soluble in water, which had a brown colour, and tasted like mucilage. From 400 grains of wheaten straw I obtained five grains of a similar substance.

There can be no doubt that the straw of different crops immediately ploughed into the ground affords nourishment to plants; but there is an objection to this method of using straw from the difficulty of burying long straw, and from its rendering the husbandry foul.

When straw is made to ferment it becomes a more manageable manure; but there is likewise on the whole a great loss of nutritive matter. More manure is perhaps supplied for a single crop: but the land is less improved than it would be, supposing the whole of the vegetable matter could be finely divided and mixed with the soil.

It is usual to carry straw that can be employed for no other purpose to the dunghill, to ferment, and decompose; but it is worth experiment, whether it may not be more economically applied when chopped small by a proper machine, and kept dry till it is ploughed in for the use of a crop. In this case, though it would decompose much more slowly and produce less effect at first, yet its influence would be much more lasting. *

* No substance enters so largely into the composition of ordinary manure as the straw or dried stems and leaves of the cereals and other plants; and yet we are far from possessing precise and accurate information on the subject. We have excellent analyses of the organic portion of the common varieties of straw, by Boussingault, and analyses of the ash or inorganic part by several chemists, but these analyses require to be repeated on the crops of different seasons, climates, varieties, soils, &c., before our information can be considered full enough for founding practical rules upon it in the most satisfactory manner. In the mean time, however, it is known, that the composition of the straw varies: 1st. With the species of plant. From Boussingault and Payen's table it will be seen, that arranging the straw of the different species according to the amount of nitrogen they contain, they fall pretty nearly into the order in which they are preferred by practical men for feeding cattle; namely,—1st, Of leguminous plants, such as peas, lentils, clover; 2d, Of the grasses cut for hay; 3d, Of white-crops, oats, wheat, barley, rye.

2nd. With the age of the plant. The straw of all plants cut when coming into flower, is richer in nitrogen, and more useful for feeding cattle, and as manure, than when the juices are allowed to be exhausted in ripening the seeds.

3rd. In different parts of the plant. Thus, in the Table, while the upper third of the straw of wheat contains 1·33 per cent. of nitrogen, the lower two-thirds of the same straw contain only ·41 per cent. The superiority of oat and barley chaff over straw is well known to practical men.

4th. The value of straw must also vary according to many other circumstances not yet much investigated: such as the length of time it has been kept, the sort of weather it experienced between the time of cutting and stacking, the soil, climate, season, &c.

Although the percentage of nitrogen is, in the main, the best, it is not the only index of the value of straw and organic bodies as manure. It has been well ascertained, that many earthy and saline substances, totally destitute of this element, exercise considerable fertilising influence on soils; and hence, *cæteris paribus*, the straw that contains the greatest amount of useful inorganic matter must be the best. Our information on the composition of the ash of straw is far from precise; and this, although to some extent owing to the want of accuracy in the earlier analyses, is chiefly due to the numerous causes of variation already mentioned.

By reference to Saussure's Table given in the 3d Lecture (pages 65-6), and particularly to Boussingault's Tables of the analyses of crops grown at Bechil-

Mere woody fibre seems to be the only vegetable matter that requires fermentation to render it nutritive to plants. Tanners' *spent bark* is a substance of this kind. Mr Young, in his excellent Essay on Manures, which gained him the Bedfordian medal of the Bath Agricultural Society, states, "that spent bark seemed rather to injure than assist vegetation;"

bronn, in the appendix to the same Lecture (page 88), it will be seen, that the percentage of ash varies much in the straw of different plants. The same thing is shewn in a more striking point of view in the following Table, compiled from a later paper, on the residua of crops, by Boussingault.—*Annales de Chimie*, 3d. series, Vol. II., page 308:—

Substances.	Inorganic Matter in 100 parts of the Substance dried in vacuo at 230° F.
Potato halm,	17·8
Leaves of field beet,	21·5
Roots of clover,	12·6
Straw of wheat,	7·0
Do. of oats,	5·1

The amount of ash in the same species has been found to vary greatly by different chemists. Some idea of the extent of this variation will be formed from the following Tables:—

Authorities.	Percentage of Ash in Wheat Straw.
Sprengel,	3·5
Noad,	3·5
Saussure,	4·3
Berthier,	4·4
Johnston, (grown on a clay loam,)	6·6
Boussingault, (dried at 230° F.,)	7·0
Davy,	15·5
Johnston, (grown on a calcareous soil,)	16·5

Authorities.	Percentage of Ash in Pease Straw.
Sprengel,	4·97
Boussingault, (dried at 230° F.)	11·32

In the different species, the difference in the composition of the ash is also very great. The following Table represents Sprengel's analyses of the ash from 100 parts of the straw of wheat, barley, oats, and rye:—

	Wheat.	Barley.	Oats.	Rye.
Potash,	·020	·180	·870	·032
Soda,	·029	·048	·002	·011
Lime,	·240	·554	·152	·178
Magnesia,	·032	·076	·022	·012
Alumina,	·090	·146	·006	·025
Oxide of iron,	trace	·014	·002	
Do. of manganese,	—	·020	·002	—
Silica,	2·870	3·856	4·588	2·297
Sulphuric acid,	·037	·118	·079	·170
Phosphoric acid,	·170	·160	·012	·051
Chlorine,	·030	·070	·005	·017
	3·518	5·242	5·740	2·793

It might also be shewn, that the composition of the ash of the same species—

which he attributes to the astringent matter it contains. But in fact it is freed from all soluble substances, by the operation of water in the tan-pit; and if injurious to vegetation, the effect is probably owing to its agency upon water, or to its mechanical effects. It is a substance very

even of the same variety—varies when grown under slightly different circumstances.

The last table presents differences so great, as to render the necessity of a careful revisal of the subject apparent. Indeed, no subject could be pointed out more deserving of the immediate attention of societies for the advancement of agriculture, than a well contrived and accurate examination of the inorganic constituents of the plants of ordinary field culture.

The question in the text regarding the propriety of ploughing in dry straw, in place of using it as litter, and converting it into farm-yard manure, has been much agitated; and Davy's views have been often misunderstood. The question, indeed, is misstated when it is asked: Is it right, or is it wrong, to plough in dry straw as a manure? The purpose for which, and the nature of the soil to which, the manure is to be applied must determine when it is safe or right to use unfermented straw, and when it is not. Practical skill consists in knowing the nature and mode of action of both; and in applying them to the proper cases when they occur. If immediate and powerful action is required, fermented dung is to be preferred. In this case, in virtue of the moisture and azotised matters contained in the urine and excrements of cattle, fermentation is set up, and carried on so far that distribution in the soil does not entirely check it; and thus, nutritive matter is supplied abundantly to the rapidly growing crops. If, on the other hand, a smaller and longer continued supply of nourishment is required, the straw may, in some cases be ploughed in, and will, during its gradual decay, minister to growing crops. But the texture of the soil is a very important consideration. Organic matter decays very slowly in stiff clay soils, because of the imperfect admission of air. Straw ploughed in acts beneficially on such soils by increasing their porosity; the admitted air causing decay both of the straw, and of organic matter previously existing in them. Accordingly, it will be found on inquiry, that the cases where dry straw has been beneficially employed were on stiff soils, and where immediate effect was not required or looked for. On porous soils the use of dry straw is contra-indicated, by its tendency to increase an existing evil; and also because such soils have less organic matter in them, and are therefore more dependent on large supplies of rapidly acting manure. As agriculture advances there is always a greater tendency to special manuring; that is to say, to apply manures to more than one crop of a rotation; use being at the same time made of the residuary portions of crops that are not carried off the field; and this practice, except in special cases, rather precludes the employment of dry straw.

One case there is of ploughing in dry straw, which admits of no debate, namely, that of stubble. It must be ploughed in dry; and the only points regarding it that require notice are the amount of useful matter thus added to the soil, and the best methods of conducting the operation.

Boussingault, in the paper already referred to, states the weight and composition of the stubble and roots of wheat and oats. The stubble and roots of wheat from 1 hectare of land, which had yielded a crop of 1172 kilogrammes of grain, (= 1045·6 lbs. per imperial acre) after being dug up and freed from adhering earth by washing, amounted to 700 kilogrammes, dried in vacuo at 230° F., to 518 kilogrammes = 462·2 lbs. per imperial acre. Of this, the earthy and saline matter amounted to 36·3 kilog. = 32·4 lbs. per acre. Nitrogen, however, is the element most looked to in judging of the value of organic matters as manure, and of this the stubble affords 2·1 kilog. per hectare = 1·9 lbs. per acre; thus the dried wheat stubble contains the same percentage of nitrogen as farm-yard manure in its normal state.

One hectare of oats, which yielded 2031 kilogrammes of grain (= 1812 lbs. per acre) gave of clean stubble and roots 912 kilog., and dried as above,

absorbent and retentive of moisture, and yet not penetrable by the roots of plants. *

Inert peaty matter is a substance of the same kind. It remains for years exposed to water and air without undergoing change; and in this state yields little or no nourishment to plants.

Woody fibre will not ferment unless some substances are mixed with it which act the same part as the mucilage, sugar, and extractive or albuminous matters, with which it is usually associated in herbs and succulent vegetables. Lord Meadowbank has judiciously recommended a mixture of common farm-yard dung for the purpose of bringing peats into fermentation; any putrescible or fermentable substance will answer the end; and the more a substance heats, and the more readily it ferments, the better will it be fitted for the purpose.

Lord Meadowbank states, that one part of dung is sufficient to bring three or four parts of peat into a state in which it is fitted to be applied to land; but of course the quantity must vary according to the nature of the dung and of the peat. In cases in which some living vegetables are mixed with the peat, the fermentation will be more readily effected. †

650 kilog. = 579·9 lbs. per acre, of which the inorganic matter amounted to 29·5 lbs. and the nitrogen to 2·3 lbs per acre.

Boussingault also determined the weight and composition of the roots of clover, which it may be as well to state in this place. One hectare of clover which yielded 2500 kilogrammes of hay, gave of roots 2000 kilog., which thorough-drying reduced to 1547 kilog. = 1380·2 lbs. per acre. And the inorganic matter of this quantity amounted to 173·9 lbs., and the nitrogen to 24·9 lbs. per acre. The clover roots being fresh and juicy readily undergo decomposition, and the very large quantity of nutritive matter thus added to the soil explains the well known effect of clover on the succeeding grain crop.

In cases where the sickle is used a considerably greater length of stubble is left, than when the grain crop has been cut by the scythe, so useful and desirable in many other respects. The porosity given to stiff soils by the bulky stubble of sickle-cutting is the strongest argument that has been urged for retaining its use on carse and clay lands.

With respect to the best method of ploughing in stubbles, little requires to be said. In stiff land, the sooner it is ploughed down the better; both because the fresher the roots, the more rapidly do they decompose, and because the action of the frost opens the soil and admits the air and moisture necessary. On porous soils, however, stubbles are often treated otherwise; the method of *break-furrowing*, as it is termed in Scotland, being had recourse to. The field is ribbed, that is to say, only every alternate furrow-slice is turned, and being laid on the space adjoining it, the stubbles of the very thin turned slice are applied to those of the undisturbed one; where, from free access of air they decompose; while the otherwise too friable soil is not too much disintegrated by frost.

* This is one of the forms of organic matter most difficult to deal with; and unless in the absence of almost all other bodies capable of being converted into manure, it is rarely had recourse to. It might be employed unaltered to improve the texture of stiff clays, and has occasionally been so used with advantage. When employed for more active purposes, it requires to be mixed with substances capable of inducing decay. Thus it is sometimes mixed with earth and lime, with earth and dung, or earth and sea-weed; and at the last turning with a small quantity of rape-dust, or very fine prepared bone-dust.

† In preparing peat for compost, it is always necessary to have it dug and exposed in heaps or ridges to the action of the air for a considerable time before it is mixed with any thing. It often happens that farm-yard manure cannot be spared for the purpose of fermenting peat; and in that case any other sub-

Tanners' spent bark, shavings of wood and saw-dust, will probably require as much dung to bring them into fermentation as the worst kind of peat.

Woody fibre may be likewise prepared so as to become a manure by the action of lime. This subject I shall discuss in the next Lecture, as it follows naturally another series of facts, relating to the effects of lime in the soil.

It is evident from the analysis of woody fibre by MM. Gay Lussac and Thenard, (which shews that it consists principally of the elements of water and carbon, the carbon being in larger quantity than in the other vegetable compounds) that any process which tends to abstract carbonaceous matter from it, must bring it nearer in composition to the soluble principles; and this is done in fermentation by the absorption of oxygen and production of carbonic acid; and a similar effect, it will be shewn, is produced by lime.

Wood-ashes imperfectly formed, that is, wood-ashes containing much charcoal, are said to have been used with success as a manure. A part of their effects may be owing to the slow and gradual consumption of the charcoal, which seems capable, under other circumstances than those of actual combustion, of absorbing oxygen so as to become carbonic acid.*

In April, 1803, I enclosed some well burnt charcoal in a tube half filled with pure water, and half with common air; the tube was hermetically sealed. I opened the tube under pure water in the spring of 1804, at a time when the atmospheric temperature and pressure were nearly the

stance capable of ready decomposition may be employed. The following method I have repeatedly tried, and found it to raise a better crop of turnips than the ordinary dose of farm-yard manure, namely, 20 tons per acre. Ten tons of half-dried peat, that had been several times turned and well exposed to the air, were mixed with six bushels of sifted bone-dust, weighing 56 or 58 lbs. per bushel, and turned. At the next turning the mass was mixed with 56 lbs. of sulphate of ammonia, and as much nitrate of soda. After standing for a few days, it was fit for use. Quick-lime is, of course, inadmissible in such a compost, unless indeed it has been mixed with the peat months before the addition of the other substances. The expense of this mixture is somewhat greater than that of Lord Meadowbank, but it is far more efficient and lasting in its effects.

* Wood-ashes are known to form a very valuable manure. In countries where wood abounds, and particularly where it is an object to clear the land, the trees are burnt, and the ashes lixiviated for the potash they contain; after which, the insoluble residue is either used as manure, or thrown away. The efficacy of the ash is due to the saline and earthy constituents, rather than the charcoal it may contain. The inorganic constituents of different plants having a general resemblance to each other, it is obvious that wood-ashes cannot fail to prove highly useful; and a supply of the insoluble portion, or lixiviated ash, might be obtained from Canada, where it is seldom applied to the land. On the continent, lixiviated wood-ash is largely employed, especially as a dressing for clover and grain crops.

In this country little wood-ash can be procured. At saw-mills, where steam-power is employed, large quantities of saw-dust are burnt along with coals in generating the steam; but the wood-ash being light, the greater part of it is carried up the chimney; so that what remains is comparatively of little value. I have several times tried the alkalinity of this ash, and found it little better than common coal-ash.

The following Table, compiled from Berthier, shews the composition of 100 parts of the soluble portion of the ash of some of the common woods, of 100 parts of the insoluble portion, together with an estimate of the phosphates of

same as at the commencement of the experiment. Some water rushed in; and on expelling a little air by heat from the tube, and analysing it, it was found to contain only seven per cent. of oxygen. The water in the

lime and iron. Common lixiviated wood-ash still retains small portions of the alkaline salts, on which its value partly depends; but the earthy salts, and particularly the phosphates, are its most valuable constituents.

		Oak.	Chesnut.	Beech.	Linden.	Birch.	Alder.	Scotch Pine.	Norway Pine.
Alkaline Salts.	Carbonic Acid,	28·4	18·8	22 4	28 2	17·0	15·2	20·8	22·8
	Sulphuric Acid,	5·9	8·7	7·3	7·6	2·3	21·0	12·0	10·0
	Muriatic Acid,	4·0	·5	5·2	1·8	·2	·9	6·7	1·6
	Silica,	1·0	2·7	1 0	1·7	1·0	·3	1·4	·5
	Potash,	60 7	69 3	64·1	60·7	79·5	62 0	31·7	64·1
	Soda,							25 4	
		100·0	100·0	100·0	100·0	100·0	100 0	98·0	100·0
Insoluble Matter.	Carbonic Acid,	30·1	30·5	32·9	39·8	31·0	28·0	36·0	35·8
	Phosphoric Acid,	7·0	1·9	5·7	2·8	4·3	11·0	1·0	4·4
	Silica,	1·7	8·5	5·8	2·0	5·5	3·3	4·6	3·3
	Lime,	44·7	51·1	42·6	51·8	52·2	50·8	42·3	69·5
	Magnesia,	7·9	3·8	7·0	2·2	3·0	—	10·5	—
	Oxide of Iron,	·1	3·5	1·5	·1	·5	2 0	·1	—
	— of Manganese,	2·9	—	4·5	·6	3·5	4·9	·4	7·0
	Carbon, &c.,	4·5	—	—	—	—	—	4·8	—
		98·9	99·3	100·0	99 3	100 0	100·0	99·7	100·0
	Phosphate of Lime,	13·9	—	7·1	5.4	7·3	15·0	1·8	9·0
	—— of Iron,	·2	3 0	3·7	·3	1·3	5 0	·2	—

However the case may be with imperfectly burned charcoal, thoroughly prepared charcoal is one of the most indestructible substances, and if it is of service as a manure, independently of the saline and earthy salts it contains, it must be chiefly from its great power of absorbing gases. Charcoal recently ignited, and cooled without access of air, is capable of absorbing and condensing in its pores a considerable quantity of gaseous matter. The charcoal of different woods varies in this respect, in consequence of the different texture of the woods; charcoal from wood of close grain and small pores absorbs most. The gases that are most readily condensible by cold and pressure are absorbed in largest quantity. It is this property that renders charcoal useful as a disinfecting agent.

The following Table contains Saussure's estimate of the quantities of different gases absorbed in 24 or 36 hours by charcoal of box-wood.

	Volumes.	
Hydrogen,	1·75	
Nitrogen,	7·5	
Oxygen,	9·25	
Carbonic oxide,	9·42	
Olefiant gas,	35·	
Carbonic acid,	35·	
Nitrous oxide,	40·	
Sulphuretted hydrogen,	55·	or 81· (Henry)
Sulphurous acid,	65·	
Muriatic acid,	85·	
Ammoniacal gas,	90·	

It is also worthy of notice, that when charcoal is exposed to the air, it absorbs

tube, when mixed with lime-water, produced a copious precipitate; so that carbonic acid had evidently been formed, and dissolved by the water.

Manures from animal substances, in general, require no *chemical* preparation to fit them for the soil. The great object of the farmer is to blend them with the earthy constituents in a proper state of division, and to prevent their too rapid decomposition.

The entire parts of the muscles of land animals are not commonly used as manure, though there are many cases in which such an application might be easily made. Horses, dogs, sheep, deer, and other quadrupeds that have died accidentally, or of disease, after their skins are separated, are often suffered to remain exposed to the air, or immersed in water till they are destroyed by birds or beasts of prey, or entirely decomposed; and in this case most of their organised matter is lost for the land in which they lie, and a considerable portion of it employed in giving off noxious gases to the atmosphere.

By covering dead animals with five or six times their bulk of soil, mixed with one part of lime, and suffering them to remain for a few months; their decomposition would impregnate the soil with soluble matters, so as to render it an excellent manure; and by mixing a little fresh quicklime with it at the time of its removal, the disagreeable effluvia would be in a great measure destroyed; and it might be applied in the same way as any other manure to crops. *

both air and moisture; but the air it takes up is not the mixture found in the atmosphere, but one much richer in oxygen.

Animal charcoal that has been used in sugar-refineries, for the purpose of removing colouring matter, forms a very valuable manure; and is employed in this country, and to a much greater extent in France. The black of the foreign sugar refineries contains, in the dry state, according to Boussingault and Payen, from 20 to 22 per cent. of blood, employed in the clarification of the syrup. This blood they regard as the active principle of the black as a manure, and the carbon is found so to modify and retard its decomposition, that an effect is obtained six times greater than would be got from the blood it contains used alone. So well and economically does the carbon regulate the decay of the blood, that the sugar refiners sell the spent black at a price which more than covers the original cost of the carbon and the blood. This fact shews how well suited charcoal, particularly animal charcoal, is for forming part of all composts rich in decaying animal bodies; and accordingly, it has been found that some of the artificial manures prepared on this principle, have given great satisfaction. It is, however, to be regretted, that many worthless imitations and nostrums have been brought into the market and puffed off in the most unprincipled manner, by means of false analyses, or at any rate by analyses of samples very different from the stocks of the venders, to the injury both of the farmer and of the manufacturer of the genuine article, to say nothing of the effect in retarding agricultural improvement. The remedy for this evil obviously is, that no *occult* preparation should be purchased, till a sample from the stock has been analysed by a competent chemist. In Boussingault and Payen's Table, there will be found estimates of the black of sugar refineries, of the animalised black, and of the charcoal used for disinfecting the sewers and cess-pools of Paris.

* The value of all animal matters is now so well understood, that carcasses are seldom allowed to remain exposed to the air. This arose at first from the general appreciation of bone-dust as a manure, and the consequent increase in the value of unbruised bones. Some years ago it was common at provincial tanneries to cut off the soft parts of animals that the skeleton might the sooner dry in the air and the bones be made available, now, however, the value of the soft parts is as much appreciated as that of the bones; and the carcasses are uniformly covered with earth or some absorbent substance till the bones can be

Fish forms a powerful manure in whatever state it is applied; but it cannot be ploughed in too fresh, though the quantity should be limited. Mr Young records an experiment, in which herrings spread over a field and ploughed in for wheat, produced so rank a crop, that it was entirely laid before harvest.

The refuse pilchards in Cornwall are used throughout the county as a manure, with excellent effects. They are usually mixed with sand or soil, and sometimes with sea-weed, to prevent them from raising too luxuriant a crop. The effects are perceived for several years.

In the fens of Lincolnshire, Cambridgeshire, and Norfolk, the little fish called sticklebacks, are caught in the shallow waters in such quantities, that they form a great article of manure in the land bordering on the fens.

It is easy to explain the operation of fish as a manure. The skin is principally gelatine; which, from its slight state of cohesion is readily soluble in water: fat or oil is always found in fishes, either under the skin or in some of the viscera; and their fibrous matter contains all the essential elements of vegetable substances. *

readily detached, and great value is put on the heap of compost thus prepared. Lime is never added to the earth used to cover carcasses, but vitriol is occasionally poured on the top of the heap for the purpose, the workmen say, of preserving the flesh. This is one of the many cases where experience has elicited as sound a rule as could have been dictated by science. Quick-lime is appropriately enough applied to peat and inert vegetable matter; but when applied to destroy the smell of decaying animal matter it is always with great loss; and vitriol, although had recourse to on an erroneous theory, is by much the best substance that could be applied. The earth should be rich in vegetable matter; and nothing is better than partially dried peat.

In large towns the soft parts of carcasses are managed differently. Having been detached from the bones, they are heated along with vitriol till their texture is completely destroyed, and the solution is mixed with charcoal and other dry absorbent matters. This preparation has given great satisfaction as a manure.

* All along the sea-coasts, much value is set on the offal or refuse collected at the fishing villages and curing stations; although, in most cases, from ignorance and mismanagement, considerable loss takes place; rendering this source of rich manure less productive then it ought to be. The supplies in Scotland are of three kinds; 1st, the refuse of the ordinary fishing for haddock, cod, ling, &c., carried on throughout the year; 2nd, the refuse of the herring fishing carried on for a short period of the year; and 3d, occasional and very irregular supplies of spoiled herrings, when they happen to be caught in larger quantities than can be cured.

When fishing villages are situated in the vicinity of large towns, it is most profitable to sell the fish in a fresh state, and for the most part they are sold ungutted; and hence, the offal finds its way with street-sweepings and the like to the public depositaries. When the villages are situated at a distance from great markets, the fish are landed at the villages and salted and preserved in various ways. The offal is preserved in rude pits, and sold to the neighbouring farmers; but as it undergoes very rapid decomposition, it is becoming customary to mix it with earth of peat. Great waste, however, generally takes place from the ignorance of the fishermen. The pits are always situated in front of the cottages, often dug in gravel or porous soil, and unprotected from rain and surface water; hence, whenever it rains, a great deal of the most valuable of the contents is carried off. Wherever it is found impossible to effect the removal of these pits to more appropriate places, and to exclude rain and surface water, tanks might be formed at little expense for receiving the drainings, and in which

Amongst oily substances, *graves* and *blubber* are employed as manure. They are both most useful when mixed with soil, so as to expose a large surface to the air, the oxygen of which produces soluble matter from them. Lord Sommerville used blubber with great success at his farm in Surrey. It was made into a heap with soil, and retained its powers of fertilizing for several successive years.

they might be neutralised, and mixed with any absorbent matters. It is probable, that in the vicinity of establishments for the manufacture of artificial manures, the fishermen will soon learn that the offal, so valuable, might be sold in a recent state at greater prices than they have hitherto obtained for it.

The refuse of the herring fishery is much more economically managed, as it is with the curers and not with the fishermen that the farmers have to deal. This refuse consists of the guts removed from the herrings before they are salted; and towards the close of the season the process of gutting cannot be effected without discharging a little of the milt and roe. Another kind of refuse which occurs in the process of curing, and which is also used as manure, is the waste brine or pickle, containing a good deal of blood and oily matter. This brine is run off the casks when, after standing the time prescribed by law, they are opened to have the vacant space occasioned by shrinking filled up with fish. A quantity of brine and undissolved salt also occurs in the casks emptied to fill the rest; and in greater quantity still, in the casks in which ungutted herrings have been salted previous to being smoked.

The herring refuse is purchased by farmers in a fresh state, and is highly valued. Like the refuse of the fishing villages, it is always made into compost; and employed either for green-crops, or in smaller doses for grain-crops. Fish refuse is a very powerful manure, but is considered less permanent in its effects than that of the farm-yard; and it has frequently occurred, that too large a dose of it incautiously applied to light land, has, after enabling it for a few years to produce great crops, ultimately left it permanently injured, particularly as to the power of carrying grain-crops. The brine and salt are occasionally mixed in the same compost heap with the refuse; but the best farmers prefer to keep them separate, and consider that compost containing brine is most applicable to grass and grain-crops, while the fish-refuse is most economically applied to the growth of turnips: this, however, applies chiefly to districts in which little wheat is grown.

Fish refuse is a very important source of manure as respects the large supply of it that might be procured, were it economically managed; as well as its richness in nitrogen and saline matters, particularly phosphates. In the absence of a specific analysis, it may be safely assumed that the recent refuse contains 4 per cent. of nitrogen; hence, so far as this element is concerned, it will be 10 times as powerful as farm-yard manure. And if 20 tons of the latter be assumed as the green-crop dose for an acre, 2 tons of refuse, properly made into compost, should produce an equal effect; and it has been found in practice to do so. Ten crans of green-fish yield one barrel of refuse. From the last published report of the Commissioners for the British Fisheries, it appears, that during the fishing of 1841 there was cured at all the stations, and they are almost exclusively Scotch, a total of 667,245 barrels, of which 489,620 barrels were gutted, and would afford 48,962 barrels of refuse, (guts) or about 6351½ tons; capable of manuring 3175¾ acres for a whole rotation commencing with green-crop, and requiring no other supplies than the residua of the crops during its remaining years; and forming an equivalent for 63,515 tons of farm-yard manure. If applied to grain crops in doses equivalent to from 5 to 10 tons of farm-yard manure, the herring refuse of this one season would have dressed from 6351½ to 12,703 acres.

All along the east coast of Scotland, except indeed at a few of the most northern and insular stations, where it can be got for the carriage, or when not thus removed is thrown into the sea, herring refuse sells, on an average, at two shillings per barrel; a price, which for the quantity above specified, gives a total

The carbon and hydrogen abounding in oily substances fully account for their effects; and their durability is easily explained from the gradual manner in which they change by the action of air and water. *

value of £4896. Supposing the carriage and mixing to cost as much more, this manure would still cost the farmer little more than half the price of good farm-yard manure.

With respect to the brine, while a part of its effect is due to the blood and oily matter it contains, it is on the salt that its efficacy principally depends; and it is unfortunate that the expense of carriage prevents it from being conveyed far inland, where it would have more effect than on the sea-coast. A barrel of herrings affords on an average three gallons of waste brine, containing in solution about 12 lbs. of salt, which gives for the total quantity cured, gutted and ungutted, in the season before mentioned, 3574 tons of salt; and including the undissolved salt found in the casks that have been emptied to fill up the rest, the salt amounts to 3674 tons. Reckoning 2 cwt. a sufficient dressing for an acre of grass or grain crop, this quantity would dress 36,740 acres. The brine is generally sold at sixpence per barrel, which gives for the quantity mentioned £1929. At many stations the brine is not so carefully saved as it might be; and at the beginning of the season when the fish are in the best condition, it is in greater demand than towards the close.

It occasionally happens, that herrings are caught in greater numbers than can be cured in good condition; when this is the case, the remainder is sold for manure; but the fish are formed into compost in the same way as the ordinary refuse, and never spread on the surface and ploughed in fresh. In most seasons, dog-fish are caught in the herring nets in considerable quantities. They are generally sold by the fishermen for the same purpose at sixpence per score.

There do not exist so good data for calculating the amount of refuse yielded annually by the ordinary fishing; but as it is not like the herring fishing, confined to certain localities, but is carried on all round the coasts, and uninterruptedly throughout the year, and moreover, as a larger proportion of offal is obtained, often including the heads of the fish, it is probable that three times as much refuse might be obtained from the fishing villages as from the herring curing stations, were it managed with economy.

* From its high price, pure oil or unboiled blubber would probably never have been thought of in Scotland as a manure, had it not been stated that various parties in England had succeeded in raising large crops of turnips with comparatively small doses of oil. Various trials have recently been made in the vicinity of Peterhead, a port to which many of the vessels employed in the Greenland and Davis' Straits fishing belong; and it has been found that to apply the oil directly to the soil does not answer, the young plants being invariably killed off. When, however, the oil is previously mixed with sifted earth, and the compost several times turned, the plants are not killed; but then, to obtain a fair crop, it has been found to require a larger quantity of oil than can be afforded, as compared either with bone-dust or farm-yard manure; and further, that the oil causes the plants to run too much to leaf, the bulbs being unusually small. In the same locality refuse blubber has been much employed. The raw oil and blubber as brought home are transferred to boilers into which a little water has been previously put. Heat is then applied, which causes the oil to separate and rise to the surface, the membranes and other refuse settling down among the water. When the oil is drawn off the refuse is found thin enough to be put into casks. This refuse when made into compost with earth has often been applied as a manure for turnips at the rate of a ton and a quarter per acre; but like the oil, it causes the plants to run too much to tops. The blubber compost is most esteemed as a manure for grain-crops, such as oats, after lea. It is spread on the surface in autumn, and ploughed in.

Among the Orkney and Shetland isles a species of whale, the *Delphinus melas* of Professor Traill, occurs in herds as a visitant of the shores and bays, and is not unfrequently driven on shore in large numbers. After the carcasses

Bones are much used as a manure in the neighbourhood of London. After being broken and boiled for grease, they are sold to the farmer. The more divided they are, the more powerful are their effects. The expense of grinding them in a mill would probably be repaid by the increase of their fertilizing powers; and in the state of powder they might be used in the drill husbandry, and delivered with the seed in the same manner as rape-cake. *

are stripped of the blubber, the soft parts are occasionally mixed in compost for manure. It is a pity that it is not always so; for in a climate highly favourable to the cultivation of the turnip, and with soils generally abounding in inert vegetable matter, no manure more suitable could be devised. The successful use of these carcasses in compost has led to a new source of animal manure in the north of Scotland, namely, the bringing home the carcasses of the Seals killed for oil in the northern fisheries. Hitherto merely a beginning has been made; but that beginning has been so successful, that henceforth, when vessels of considerable tonnage go to the Seal fishery, it is evident that stowage can easily be afforded for bringing home the carcasses, and thereby diminishing the chance of loss from a deficient fishing. It also deserves consideration, whether the soft parts of whales might not in the same way, be worth bringing home from the Greenland and Davis' Straits fisheries. The bones of whales, although valuable as manure, are considerably less so than those of land mamifers.

* Of all extraneous manures, bone-dust was the first that attracted much attention; and from the moderate price at which it has been supplied from foreign countries, coupled with its applicability to almost every variety of crop, it has come into very general use. Bones have for many years been imported into this country from almost all the principal ports of the north of Europe, and for some time, although in less quantity, from the South of Europe and even South America. Most of these are what are termed raw bones; that is, they have never been boiled. The greater portion appear to have been buried in the earth or in compost, till the soft parts could be detached, but many also appear to have been derived from carcasses whose soft parts have decayed in the air. From certain of the German ports some of the bones appear to have been boiled for glue, and these, although they are more easily bruised and act more rapidly, are not so much esteemed. From Russia the bones are partially bruised, just enough to cause them to occupy less room in stowage, and to comply with a regulation which prevents their exportation unless more or less manufactured. From the South the bones are drier, more brittle, capable of being reduced to finer division of parts, and consequently of more uniform distribution in the soil; but they are more rapid and evanescent in their action. Bones, particularly those from ports where the trade has been longest carried on, are frequently much adulterated with stones, hoofs, horns, and every cheap waste matter that adds to the weight; generally rendering it necessary for the manufacturer in this country to have recourse to hand-picking, to prevent the hard or tough foreign bodies from breaking or injuring the teeth of the cylinders employed in crushing. From the South the bones are generally free from adulteration; but the best quality consists of bones collected in the large towns of Britain itself; from this source, however only a small portion of the supply can be derived.

Mr Meek's report on Agricultural Produce and Shipping in Northern Europe, printed by order of the House of Commons in February, 1842, furnishes some data, from which an idea of the extent of the trade in this article may be obtained. Of eleven ports reported on, two were found to export none; concerning Hamburg which is known to export largely, no information could be obtained; but the remaining eight, namely Rotterdam, Bremen, Kiel, Lubeck, Rostock, Stettin, Dantzic and Elsenore, the total annual export amounted to 13,084 tons.

Bone-dust is much used all over Scotland, but in no district so universally

Bone-dust, and bone-shavings, the refuse of the turning manufacture, may be advantageously employed in the same way.

The bases of bone is constituted by earthy salts, principally phosphate of lime with some carbonate of lime and phosphate of magnesia; the easily decomposable substances in bone are fat, gelatine, and cartilage, which seems of the same nature as coagulated albumen.

as in Aberdeenshire and the adjoining counties, where it is for the most part applied in supplement to farm-yard manure in growing turnips. During the year from 1st June 1840 to 1st June 1841, there were imported into Aberdeen from foreign parts 4355½ tons; and on an average of the last six years 3461 tons annually.

The best bone-dust is found to weigh 54 lbs. per bushel, and reckoning 20 bushels of such dust a sufficient dose for an imperial acre of turnips, the average quantity imported into Aberdeen should dress 7178½ acres; and that not merely for the green crop, but for the whole of the usual five or six course rotation. And used in supplement to a dose of 10 tons of farm-yard manure, the more common, and certainly more profitable way of using it on open soils, the 3461 tons would suffice for from 14,356 to 17,946 acres.

As bones, unless in fine division of parts, decompose slowly in the soil, it is of advantage to have them crushed as small as possible; and of late years this has been becoming better understood, and bone-dust manufacturers have had increased difficulty in selling the large size usually called *drill*. When bones alone are used as a manure for turnips, and when the soil is very open, it is found advantageous to use a mixture of dust and drill, to carry on the growth in autumn; but as the drill remains long undecomposed, it is better still to use farm-yard manure along with a small dose of fine bone-dust, dispensing entirely with the drill. Bone-dust is generally sold by measure, and manufacturers are thus able to sell the rough ground sorts at apparently smaller prices. It is always the farmer's safest course, however, to purchase bone-dust as he sells grain, namely, by weight and measure combined; not scrupling to give a higher price for a bushel of proportionally greater weight; for not merely does he sooner derive benefit from the finely divided bones, but by their being more generally distributed through the soil, they do incalculably more good to the grain and grass crops that succeed the turnips. A bushel of well ground bone-dust should weigh 53 to 54 lbs., 1 of drill 40 to 41 lbs., and 1 of mixed dust and drill 46 to 48 lbs.

Many of the bones imported being damp, when bone-dust is allowed to remain in large heaps for some time subsequent to grinding, it undergoes a partial fermentation, and diminishes in bulk. Dust that has undergone this action is always preferred to that which is fresh ground, and when sold by measure alone, is worth a better price. It is of course the manufacturer's interest to sell bone-dust immediately after it is ground.

The substances that have been mentioned as adulterants of bones are almost all removed before crushing, so that the only thing ever met with in dust purchased from respectable parties, is a very small percentage of sand and earthy matter, whose amount can readily be made manifest by agitating a quantity of the dust with water, allowing the mixture to subside in a precipitate glass, and subsequently examining the lowermost stratum. It rarely amounts to as much as would sensibly diminish the commercial value of the article.

Bone-dust being ill adapted to very stiff or wet soils, has hitherto been principally applied as a manure for the green crop which commences the rotation in open soils. When the soil is very decidedly open, bone-dust ought always to be used along with farm-yard manure, the manure being first spread in the drills and the dust sown above it, before covering in with the plough. In some districts a machine called a bone-dust dropper is used to deposit the dust above the manure in small quantities, at 10 inches apart. This is a cheap and effectual substitute for dibbling; its only disadvantage being, that the grain-crop which follows is liable to grow in tufts, from the bone-dust being too much confined to

According to the analysis of Fourcroy and Vauquelin, ox bones are composed

Of Decomposable animal matter, . . .	51
— Phosphate of lime, ...	37·7
— Carbonate of lime, ...	10
— Phosphate of Magnesia, ...	1·3
	100

particular spots; still, however, the method is much esteemed, for it renders a very small dose of dust effectual in raising a good turnip crop, and then, a special manuring can be afforded for the next crop. The use of farm-yard along with bone-dust, is especially applicable to early sown turnips and dry seasons. Some of the doses of bone-dust have been incidentally mentioned. When used alone, 20 bushels of 54 lbs. per bushel, is the usual dose per acre; and along with farm-yard manure, 8 to 10 bushels, with 10 tons of the latter. When bone-dust is used as a special manure for grain crops, 8 bushels of the above weight is a sufficient dose for an acre; and it is never ploughed in, but sown and harrowed in with the seed, that it may be as near the roots as possible, and not far removed from the air. Applied to meadow or old pasture, the best form is to give fine bone-dust in compost with earth and urine, at such a rate, that 8 to 10 bushels of dust go to an acre.

Since Liebig called attention to the superiority of bone-dust treated with sulphuric acid over common bone-dust, the subject has met with much attention from farmers, especially in the north of Scotland; and the practice has been found so decidedly advantageous, that it may now be considered as completely established in the districts where it was first tried, and its extention to others is rapidly taking place. Liebig's formula was at first followed, namely, "to pour over the bones, in a state of fine powder, half their weight of sulphuric acid diluted with three or four parts of water," and after digesting for some time, "to add 100 parts of water." Several serious difficulties, however, stand in the way of farmers making the preparation for themselves; thus, the expense and hazard attending the carriage of vitriol, the chance of accidents to farm-servants, who are quite unaccustomed to the use of vitriol, the absence of all suitable vessels in which to conduct the digestion, and above all, the trouble of making the preparation and the expense of distributing so dilute a substance. The force of this last objection becomes more apparent when it is considered, that for every bushel of sifted bone-dust (58 lbs.), there require to be carried to the field 26 cwt. of solution—a thing not easily effected in the busy season of turnip-sowing. From experience of these difficulties, I was led some years ago, to try a dry preparation of bone-dust with sulphuric acid; and this dry preparation has been found to combine so many advantages, that it is now very generally adopted in the county of Aberdeen. For making this preparation the finest bone-dust is employed. Dust prepared from bones from the north of Europe may be got, by sifting, of the weight of 58 lbs. per bushel; but as the dry bones from the south readily yield it of the weight of 75 lbs., the latter is of course to be preferred. Any convenient quantity of dust is laid in an oblong heap on a flagstone floor, a depression is made in the top of the heap, and one-fourth part of its weight of concentrated sulphuric acid is added in small quantities at a time, the mass being thoroughly turned and mixed by means of wooden shovels after each addition of acid. Alternately with each portion of acid, as much water is added. When the whole acid and water have been added and the mixture is completed, the mass is hot and somewhat moist; after lying in the heap for a day or two, it becomes quite dry, and is fit for sowing, either by hand or machine. The quantity of sulphuric acid in this mixture is but half that used in the liquid way, but it has been ascertained by many trials, that any increase above the quantity recommended is not so economical; and, indeed, where, as occasionally happens, sifted bone-dust cannot be obtained, a further

M. Merat Guillot has given the following estimate of the composition of the bones of different animals :—

	Phosphate of Lime.	Carbonate of Lime.
Bone of Calf, ...	54	
..... Horse, ...	67·5	1·25
..... Sheep, ...	70	5
..... Elk, ...	90	1
..... Hog, ...	52	1
.... Hare, ...	85	1
..... Pullet, ...	72	1·5
... . Pike, ...	64	1
..... Carp, ...	45	5
Horses' Teeth, ...	85·5	2·5
Ivory, ...	64	1
Hartshorn, ...	27	1

The remaining parts of the 100 must be considered as decomposable animal matter. *

diminution may be made with advantage. Concentrated sulphuric acid has been specified, but in places where only unconcentrated acid is made, it is cheaper to use that, a proportionally greater weight being employed. The value of the acid is of course determined by the hydrometer; and it should be of the kind made from sulphur, and not from pyrites, as the latter generally contains a large quantity of arsenic. Although of this dry preparation a larger dose is required than of the wet one, the advantages attendant on its use render it, on the whole, a cheaper preparation. Some of its advantages are, that it is prepared by the manufacturer, who can go to a better market for all the materials than the farmer, and from conducting the operation on a large scale, can make it of better quality, both from the employment of suitable machinery, and from the skill acquired by the workmen; and further, the expense of carriage and application to the land is not greater than that of an equal weight of unprepared bone-dust.

After many trials it has been ascertained, that unless in land containing a considerable proportion of organic matter, neither the liquid nor the dry preparation should be used alone as a manure for turnips, but in addition to a moderate dose of farm-yard manure. The prepared bone-dust has the effect of causing the turnip plants to come away more early and vigorous than any other manure, and it also hastens their maturity; points of great importance when the turnips are to be succeeded by winter wheat; but when this is not the case, and particularly when the summer and autumn have been dry and hot, the bulbs stop growing before they attain the weight they would do, were a slowly decomposing substance, like farm-yard manure, used along with the prepared bone-dust. From comparative trials on all varieties of turnip soils, it has been found, that 5 or 6 bushels of the dry preparation, given in addition to 10 tons of farm-yard manure per acre, give 4 or 5 tons of bulbs more than could be grown on the same soils by 20 tons of farm-yard manure alone; and that the subsequent crops, particularly the clover, are also improved. The dry preparation has also been found a cheap and very efficient special manuring for grain-crops and grass. When used for grain crops, the best results have been got when it was applied to a grain-crop immediately succeeding a green-crop grown after farm-yard manure alone, and here too, the same tendency to bring the plants early to maturity is manifested, the grain being ready for reaping fully a fortnight before portions of the same crop dressed with other manures; the weight of the grain per bushel being increased, and the straw firm and healthy. Bone-dust, with sulphuric acid, has also been found to answer well for potatoes, especially when mixed with a little sulphate of magnesia.

* As might have been expected, there exists more precise information regard-

Horn is a still more powerful manure than bone, as it contains a larger quantity of decomposable animal matter. From 500 grains of ox horn Mr Hatchett obtained only 1·5 grains of earthy residuum, and not quite half of this was phosphate of lime. The shavings or turnings of horn form an excellent manure, though they are not sufficiently abundant to be

ing the composition of human bones than those of the lower animals. Marchand's analysis, while more minute in some of its details, corresponds so well with that of Berzelius, that it may be taken as the best. The bone selected was a thigh bone of an adult male, and previous to analysis, it was freed from periostium and fat, and of course thoroughly dried. It was found to consist of:—

Cartilage insoluble in muriatic acid,	27·23
——— Soluble ———,	5·02
Vessels,	1·01
Basic phosphate of lime,	52·26
Fluoride of calcium,	1·00
Carbonate of lime,	10·21
Phosphate of magnesia,	1·05
Soda,	0·92
Chloride of Sodium,	0·25
Oxides of iron and manganese, and loss,	1·05
	100·00

In very young animals the bones are soft, and consist principally of cartilage in which the earthy part is gradually deposited; so that the relative proportion of these constituents depends on age. In adults of the same species the fatty matter varies with the food, habits, and condition. According to Frerichs, the relative proportion of organic and inorganic matter varies, in different bones of the same individual, according to the texture of the bones; those of a loose and spongy kind having more vessels, and thus more organic matter, although the ratio of the cartilage to the earthy part may not be sensibly different from what it is in the compact bones. The following table represents the mean of four analyses by Frerichs; two of spongy bones, and two of compact bones, all from the same individual:—

	Spongy Bones.	Compact Bones.
Organic matter,	37·82	31·20
Earthy phosphates,	50·81	59·10
Carbonate of lime,	11·29	9·77

From these analyses, as well as that of Marchand, it is obvious that in bones of different texture the carbonate of lime does not bear a constant ratio to the earthy phosphates; but that it is more nearly proportional to the organic matter. The relative proportion of carbonate and phosphate of lime varies in different species. Marchand gives the following table of results from Fernandez de Barros, shewing the quantity of carbonate of lime for every 100 parts of phosphate of lime in the bones of the following animals:—

Fish,	2·52
Lion,	2·63
Frog,	5·76
Fowl,	11·70
Sheep,	24·12

In man, according to Marchand's analysis, it is 19·54. Most of the bones employed as manure being those of phytivorous animals, the quantity of carbonate of lime they contain is considerable. But the most important cause of difference in the composition of the bones imported as manure is their state of preservation. If they have been long exposed to the air, or buried near the surface of the soil, waste of the organic matter they contain must have tak-

in commom use. The animal matter in them seems to be of the nature of coagulated albumen, and it is slowly rendered soluble by the action of water. The earthy matter in horn, and still more that in bones, prevents the too rapid decomposition of the animal matter, and renders it very durable in its effects. *

Hair, *woollen rags* and *feathers*, are all analogous in composition, and principally consist of a substance similar to albumen, united to gelatine.

place. Marchand gives two analyses which illustrate this change; both were of bones of the bear, which had lain buried for an unknown period, No. 1 near the surface, No. 2 at a considerable depth:—

	No. 1.	No. 2.
Animal matter,	4·20	16·24
Phosphate of lime,	62·11	56·01
Carbonate of lime,	13·24	13·12
Sulphate of lime,	12·25	7·14
Fluoride of calcium,	2·12	1·96
Phosphate of magnesia,	0·50	0·30
Silicic acid,	2·12	2·15
Oxides of iron and manganese,	2·12	2·00
Soda,	1·34	1·08
	100·00	100·00

With respect to the action of bones as a manure, an unnecessary diversity of opinion exists, some attributing its effect to the organic matter, and others to the earthy part; and because Liebig found it necessary to attach great importance to the inorganic constituents of plants, and to the keeping up a supply of these matters in the soil, and also to shew how large a quantity of carbon plants derive from the air, some recent writers have most gratuitously assumed that he denies or underestimates the influence of the organic portion. The utility of all animal matter is so well established, that the inefficiency of the cartilage or gelatine of bones, can be made out only by shewing that it is incapable of decay; but an examination of bones that have lain in a porous soil shews, that the organic matter in them decomposes faster than horns. Burnt bones have again and again been tried side by side with unburnt bones, but without producing any thing like the same immediate effect. The circumstance already mentioned, that dry bone-dust from warm climates, and the fine bone-dust prepared with sulphuric acid are liable, under certain circumstances, to fail in maintaining the autumnal growth of turnips, is also a case in point. That phosphates exercise a beneficial influence, however, is evident from the composition of the seeds of most plants, particularly of grain and pulse; as well as from the smallness of the dose of bone-dust which will continue for many years to exercise a fertilising influence.

* Horns and hoofs decompose very slowly even when in fine division of parts, and on this account, as well as on account of the difficulty and expense of reducing them, they are not much employed as manure. Horn-raspings and shavings, however, may be obtained in some situations; and when applied under circumstances where continued action is more required than powerful and immediate effect, they form a very eligible manure. I have tried horn saw-dust as a manure for turnips, but found it much too slow in action, the turnips not having attained a greater size by the beginning of winter than those grown after bone-dust had done when but a few weeks old; yet the plants continued green and growing till checked by severe frost. As horns and hoofs accumulate in considerable quantity at bone-crushing establishments, it might be worth while to ascertain whether they could not be crushed by the ordinary apparatus after being rendered brittle by a good kiln-drying. If they could be so crushed, it would probably be most advantageous to mix them in compost for some months, and induce decomposition before applying them to the ground. An analysis of horn-raspings will be found in Boussingault and

This is shewn by the ingenious researches of Mr Hatchett. The theory of their operation is similar to that of bone and horn shavings. *

The *refuse* of the different manufactures of *skin* and *leather* form very useful manures; such as the shavings of the currier, furriers' clippings, and the offals of the tan-yard and of the glue-maker. The gelatine contained in every kind of skin is in a state fitted for its gradual solution or decomposition; and when buried in the soil, it lasts for a considerable time, and constantly affords a supply of nutritive matter to the plants in its neighbourhood.

Blood contains certain quantities of all the principles found in other animal substances, and is consequently a very good manure. It has been already stated that it contains fibrine; it likewise contains albumen: the red particles in it which have been supposed by many foreign chemists to be coloured by iron in a particular state of combination with oxygen and acid matter, Mr Brand considers as formed of a peculiar animal substance, containing very little iron. †

Payen's table. Liebig gives four analyses of Buffalo horn by Scherer, one of them is as follows:—

Carbon,	51·620
Hydrogen,	6 754
Nitrogen,	17·284
Oxygen, Sulphur,	24·342

* Hair, wool, and feathers, are all closely allied in composition. Estimates of the nitrogen contained in these bodies will be found in the table in the appendix to Lecture VI. Liebig gives the following analyses by Scherer:—

	Human Hair.	Wool.	Beard of Feather.	Quill of Feather.
Carbon,	50·622	50·653	50·434	52·427
Hydrogen,	6·613	7·029	7·110	7·213
Nitrogen,	17·936	17·710	17·682	17·893
Oxygen, Sulphur,	24·829	24·608	Oxygen, 24·774	22·467

These substances are all very useful manures, decomposing slowly, and hence requiring to be ploughed in a considerable time before the land is sown, or to be made into compost. They are particularly applicable to hops, fruit trees, and vines. One of the best ways of managing woollen rags, although not often attainable, is to have them cut into pulp by the rag-cutting machinery of paper works, and immediately run into a heap of earth to be formed into compost. This compost admits of very uniform distribution, and decay is hastened. The supply of these substances is limited; yet, were their value more generally known, more efficient means of saving and collecting them would soon be had recourse to.

† Liebig gives the following analyses of ox-blood; the first by Playfair, the second by Bœckmann:—

	I.	II.	Mean.
Carbon,	51·95	51 96	51·96
Hydrogen,	7·17	7·33	7·25
Nitrogen,	15·07	15·08	15·07
Oxygen,	21·39	21·21	21·30
Ashes,	4·42	4·42	4·42

From the analyses of blood in different states given in Boussingault and Payen's table, it will be seen, that as a readily decomposable substance containing much nitrogen, blood is among the most valuable of manures. In this country blood is seldom obtained alone, but mixed with the other offal of the slaughter-house. It is always made into compost. One of its most valuable properties is the facility with which it induces decomposition on other bodies. Blood or slaughter-house offal is therefore eagerly purchased by farmers for their compost heaps, and consequently bears a considerable price.

The scum taken from the boilers of the sugar bakers, and which is used as manure, principally consists of bullock's blood, which has been employed for the purpose of separating the impurities of common brown sugar, by means of the coagulation of its albuminous matter by the heat of the boiler. *

The different species of *corals*, *coralines*, and *sponges*, must be considered as substances of animal origin. From the analysis of Mr Hatchett, it appears that all these substances contain considerable quantities of a matter analogous to coagulated albumen; the sponges afford likewise gelatine.

According to Merat Guillot white coral contains equal parts of animal matter and carbonate of lime; red coral 46·5 of animal matter, and 53·5 of carbonate of lime; articulated coraline 51 of animal matter, and 49 of carbonate of lime.

These substances are, I believe, never used as manure in this country, except in cases when they are accidentally mixed with sea-weed; but it is probable that the coralines might be advantageously employed, as they are found in considerable quantity on the rocks, and bottoms of the rocky pools on many parts of our coast, where the land gradually declines towards the sea; and they might be detached by hoes, and collected without much trouble.

Amongst excrementitious animal substances used as manures, *urine* is the one upon which the greatest number of chemical experiments have been made, and the nature of which is best understood.

The urine of the cow contains, according to the experiments of Mr Brande,

Water,	65
Phosphate of lime,	3
Muriates of potassa and ammonia,	15
Sulphate of potassa,	6
Carbonates of potassa, and ammonia,	4
Urea,	4 †

* See note page 218.

† Sprengel gives the following analysis of cow's urine in a fresh state the animals at the time having the range of a rich pasture: 100,000 parts consisted of:—

Water,		92,624
Urea, along with some resinous colouring matter,		4,000
Mucus,		190
Albumen,		10
Benzoic acid, (hippuric acid)	combined with potash,	90
Lactic acid,	soda, and ammonia,	516
Carbonic acid,	forming salts.	256
Ammonia,		205
Potash,		664
Soda,		554
Sulphuric acid,	combined with soda,	405
Phosphoric acid,	lime, and magnesia,	70
Chlorine,	forming salts.	272
Lime,		65
Magnesia,		36
Alumina,		2
Oxide of iron,		4
Oxide of manganese,		1
Silica,		36
		100,000

See Translation in the Journal of the Royal Agricultural Society of England, Vol. I., p. 466.

The urine of the horse, according to Fourcroy and Vauquelin, contains

Of Carbonate of lime, ...	11
— Carbonate of soda, ...	9
— Benzoate of soda, ...	24
— Muriate of potassa, ...	9
— Urea, ...	7
— Water and mucilage, ...	940

In addition to these substances, Mr Brande found in it phosphate of lime.

The urine of the ass, the camel, the rabbit, and domestic fowls have been submitted to different experiments, and their constitution has been found similar. In the urine of the rabbit, in addition to most of the ingredients above mentioned, Vauquelin detected gelatine; and the same chemist discovered uric acid in the urine of domestic fowls.

Human urine contains a greater variety of constituents than any other species examined.

Urea, uric acid, and another acid similar to it in nature called rosacic acid, acetic acid, albumen, gelatine, a resinous matter, and various salts are found in it.

The human urine differs in composition according to the state of the body, and the nature of the food and drink made use of. In many cases of disease there is a much larger quantity of gelatine and albumen than usual in the urine; and in diabetes it contains sugar.

It is probable that the urine of the same animal must likewise differ according to the different nature of the food and drink used; and this will account for discordancies in some of the analyses that have been published on the subject. *

* In Boussingault and Payen's Table there will be found estimates of the value of the urine of man, cows, and horses, by the method of ultimate analysis.

The urine of all animals differs according to a variety of circumstances, such as the age of the animal, its condition and habits, the nature of its food, and of the water it drinks.

Immense loss has heretofore been sustained by the agriculturists of this country from inattention to the means of saving, fixing, and applying urine as a manure. This inattention has arisen chiefly from underestimating the utility of urine, and from the expense and inconvenience of applying so dilute and bulky a substance. From Boussingault and Payen's table it appears that so far as the nitrogen alone is concerned, it is a far more valuable substance than most practical men have thought it.

The following table represents the equivalents, or weights of the substances, that in their normal state should produce equal effects:—

Farm-yard manure, - - - - - -	100·0
Urine of milk-cows, - - - - - -	90·9
——— man, - - - - - - -	55·95
——— horse, - - - - - - -	15·3

Granting that in this case the urine of the horse is over-estimated, from the animal's drinking less water than horses usually do, it is obvious, that weight for weight, urine of any kind is far more useful than farm-yard manure; and that the expense of conveying so large a quantity of water to the field, is more than counterbalanced by the general and uniform distribution which is thus effected of the useful constituents held in solution.

Some attempts have lately been made to separate most of the useful constitu-

Urine is very liable to change and to undergo the putrefactive process; and that of carnivorous animals more rapidly than that of graminivorous animals. In proportion as there is more gelatine and albumen in urine, so in proportion does it putrify more quickly.

The species of urine that contain most albumen, gelatine, and urea, are the best as manures; and all urine contains the essential elements of vegetables in a state of solution.

During the putrefaction of urine the greatest part of the soluble animal matter that it contains is destroyed; it should consequently be used as fresh as possible; but if not mixed with solid matter, it should be diluted with water, as when pure it contains too large a quantity of animal matter to form a proper fluid nourishment for absorption by the roots of plants.

Putrid urine abounds in ammoniacal salts; and though less active than fresh urine, is a very powerful manure.

ents contained in urine from the water by precipitation; and the trials have been so far successful, as to point out this as one of the most promising methods of turning to account the urine collected in large towns. When the process is perfected, it may, perhaps, be found applicable even to the contents of the farm-yard tanks. In the mean-time, however, it is becoming common in some parts of the country to fix the ammonia, by keeping always a slight excess of sulphuric acid in the tanks; and to apply the neutralised urine either by means of the watering cask, or to pump it up and mix it in compost with earth or peat. In either case, it should be ascertained by test-paper to be quite neutral, at the time it is applied; and when it is so, a large dose of it may, with complete safety, be applied after the Flemish method to growing plants. Those who have tried this method speak highly of it, and certainly it is far preferable to the foreign plan of diluting the urine with an equal bulk of water; for even after this dilution a good deal of ammonia escapes into the air, the expense of applying it is doubled, and when put on the ground in hot weather, a further loss of ammonia takes place.

Sprengel estimates the urine of a cow at 15,000 lbs. per annum. Boussingault found that a milch cow giving 18·8 lbs. of milk per day, voided in the 24 hours above 18 lbs. of urine, or 6,598 lbs. per annum, of which, the fixed alkaline and earthy salts alone would amount to 309 lbs. Assuming that the urine voided in the fields is as well applied as that which reaches the tank, and that Boussingault's estimate is a fair average for the cattle on a farm over head, a farmer who has a stock of 50 cattle, possesses a local source of ammonia equivalent to 1779·98 lbs. per annum, which, were it all fixed by neutralising with sulphuric acid, would amount to three tons, 1½ cwt. of sulphate of ammonia. Now, this amount of sulphate of ammonia would suffice to dress 41 acres of grain-crop after lea, with the certainty of adding largely to the return both of grain and straw. But this is not all, for the fixed alkaline and earthy salts contained in the urine of 50 cattle amount to 6 tons 18 cwt., and as they are more efficient as a manure than any other mixture of salts that has yet been contrived, 1½ cwt. would be quite sufficient to dress an acre of grain-crop or grass; hence, the quantity above stated would dress 92 acres.

The whole urine can be collected only in winter, or in summer when the method of soiling is employed; that which is voided in the fields cannot of course be so well fixed, or so well applied; on the whole, however, it is sufficiently obvious, that in the construction of houses for cattle, and courts for manure, the most complete arrangements should be made for carrying the part of the urine that is not required in the preparation of the farm-yard manure, as fast as possible into tanks; and that were the urine now generally allowed to run to waste, properly collected, fixed and applied, a much less amount of bone-dust, guano, and other extraneous manures would require to be imported into the country, or with a continuance of these, the produce of the country would be greatly increased.

According to a recent analysis published by Berzelius, 1000 parts of urine are composed of

Water,	933·
Urea,	30·1
Uric acid,	1·0
Muriate of ammonia, free lactic acid, lactate of ammonia, and animal matter,	17·14

The remainder different salts, phosphates, sulphates, and muriates. *

Amongst excrementitious solid substances used as manures, one of the most powerful is the *dung* of *birds* that feed on *animal food*, particularly the dung of sea-birds. The *guano*, which is used to a great extent in South America, and which is the manure that fertilizes the sterile plains of Peru, is a production of this kind. It exists abundantly, as we are informed by M. Humboldt, on the small islands in the south sea, at Chinche, Ilo, Iza, and Arica. Fifty vessels are laden with it annually at Chinche, each of which carries from 1500 to 2000 cubical feet. It is used as a manure only in very small quantities; and particularly for crops of maize. I made some experiments on specimens of guano sent from South America to the Board of Agriculture in 1805. It appeared as a fine brown powder; it blackened by heat, and gave off strong ammoniacal fumes; treated with nitric acid it afforded uric acid. In 1806, MM. Fourcroy and Vauquelin published an elaborate analysis of guano. They state that it contains a fourth part of its weight of uric acid, partly saturated with ammonia, and partly with potassa; some phosphoric acid combined with the same bases, and likewise with lime. Small quantities of sulphate and muriate of potassa, a little fatty matter, and some quartzose sand.

It is easy to explain its fertilising properties; from its composition it might be supposed to be a very powerful manure. It requires water for the solution of its soluble matter to enable it to produce its full beneficial effect on crops. †

* Now that so much importance is attached to saline manures, it may be useful to give the full analysis; it is as follows:—

Water,	933·00
Urea,	30·10
Uric acid,	1·00
Lactic acid, lactate of ammonia, and animal matter adhering to them,	17·14
Mucus of the bladder,	0·32
Sulphate of potash,	3·71
——— of soda,	3·16
Phosphate of soda,	2·94
——— ammonia,	1·65
Chloride of sodium,	4·45
——— ammonium,	1·50
Earthy matters, with a trace of fluoride of calcium,	1·00
Siliceous earth,	0·03
	1000·00

† Within the last few years guano has been largely imported into Britain, and after having been tried on soils of all kinds, and to raise all the ordinary crops, it is generally esteemed the most valuable of extraneous manures. Hitherto it has been brought only from South America, but the demand being now con-

The dung of sea birds has, I believe, never been used as a manure in

siderable, many vessels have been fitted out to bring it from several localities on the African coast.

The South American guano varies considerably in its physical characters. The greater part of it presents the appearance of a slightly damp powder of a deep reddish-brown colour, with numerous hard lumps amongst it. Some of these lumps are found to contain stones, but most of them consist of the less decomposed parts of the guano. When broken, the fractured surface is of a whitish colour, with numerous small crystals interspersed. Another variety has a dark greyish colour, generally with more stones and fewer lumps. The best guano is said to be white, but none of this variety has yet come into the British market. The brown variety has a peculiar putrid odour, the grey variety smells very distinctly of ammonia, and is damper than the other.

The published analyses of guano differ much from one another. This was to be expected, for its composition must differ according to its age, the degree of exposure it has had to air, moisture and decomposing influences, and the admixture of stones, sand, and foreign matters. Fourcroy and Vauquelin's analysis is as follows:—

Urate of ammonia,	9·0
Oxalate of ammonia,	10·6
———— lime,	7·0
Phosphate of ammonia,	6·0
———— and magnesia,	2·6
Sulphate of potash,	5·5
———— soda,	3·3
Sal-ammoniac,	4·2
Phosphate of lime,	14·3
Clay and sand,	4·7
Water and organic matters,	32·3
	100·0

Dr. Ure, who has recently analysed guano for the importers, gives the following average result:—

Azotised organic matter, including urate of ammonia, and capable of affording from 8 to 17 per cent. of ammonia by slow decomposition in the soil,	50·0
Water,	11·0
Phosphate of lime,	25·0
Ammonia, phosphate of magnesia, phosphate of ammonia, and oxalate of ammonia,	13·0
Siliceous matter from the crops of the birds,	1·0
	100·0

Boussingault and Payen's table contains two analyses of the brown variety imported into England, one in its natural state, the other purified by sifting: the nitrogen of the first corresponds to 6 per cent. of ammonia, that of the second to 6·5 per cent., exclusive of sand and fixed foreign matter. Their table also contains an analysis of guano imported into France, through the Minister of Agriculture. This sample is described as of a greyish colour, and exhaling a decidedly putrid odour. It contained, in its normal state, 13·95 per cent. of nitrogen, which corresponds to 16·9 per cent. of ammonia. Even this specimen is inferior to one mentioned by Dr. Ure in his report, for "it contained no less than 17 per cent. of *potential* ammonia, besides 4½ per cent. of the actual or ready formed." Professor Johnston gives an analysis of one sample in which the ammonia was estimated. It contained 7 per cent., with ·8 of uric acid. I

this country; but it is probable, that even the soil of the small islands on

have examined many specimens both of the brown and grey varieties, and have found the siliceous sand very variable in both kinds, some times amounting to 15 per cent. In the grey variety I have found very little uric acid, but always more in the brown. The largest quantity of ammonia I have met with is 8·5 per cent.

For immediate effect, that which contains most ready-formed ammonia is best, but its permanency cannot be so great; and there is no doubt much ammonia lost by exposure in the bags in which it is sent out, as well as after it is applied to the land. To avoid loss of ammonia, a few trials have been made of mixing the guano with as much sulphuric acid as is necessary to convert the bicarbonate into sulphate, and the results have been favourable, but not sufficiently numerous to decide whether the gain is more than equivalent to the expense of acid and mixing. It is a method, however, that deserves attention.

There can be no doubt that guano is frequently adulterated. The farmer's safest way of avoiding a spurious or deteriorated article is to purchase only from parties whose character and integrity form a guarantee against their selling any thing that is not genuine, and who are always willing to satisfy the public by having fairly selected samples examined by competent chemists. Genuine guano is so variable in its composition and value, that if skilfully done, a fine sample might be deteriorated to a considerable extent without the possibility of detection. The cure for this obviously is, to purchase guano at a price proportionate to the amount of ascertained useful constituents it contains. Guano sometimes contains feathers, but it is a suspicious circumstance to find in it those of our domestic poultry The introduction of the term *artificial guano* has been extremely unfortunate. If by guano we simply mean manure, it would be hard to say to what substances and mixtures it might not be applied; but if by it we mean the partially decomposed excrements of sea-birds, its application to any artificial mixture however valuable, is obviously improper. Cases have occurred where from ignorance or design, dealers in extraneous manures, after purchasing the so-called artificial guano from the manufacturers, have thought proper to drop the *artificial*, and sell the preparation as guano. I have had several such mixtures put into my hands for analysis by farmers who had purchased them as genuine guano. Now, although these preparations might be useful to a certain extent, they were obviously frauds, for they did not contain a trace of genuine guano, and were sold at prices far beyond their actual value. It is not perhaps too much to expect, that if experimental agriculture be judiciously pursued, artificial mixtures cheaper and more efficient than guano may be discovered; in the meantime, however, it is for the interest of individuals, as well as the art, that these mixtures be sold under names that truly express their composition, or at all events do not mislead.

In Scotland guano has been used most extensively as a manure for turnips, and with remarkable success. Sometimes it has been employed alone, at the rate of 4 or 5 cent. per acre; and at other times in addition to ten tons of farm-yard manure, at the rate of 2 cent per acre. Many are of opinion that the roots are larger after the mixture, although in many instances, and particularly in the presence of much organic matter, the guano alone has produced very large crops. In a few localities it is thought that turnips grown after guano are more liable to decay during the winter, and to start into second growth, than those grown after farm-yard manure. Turnips manured with guano braird earlier, stronger, and more healthy in appearance than after farm-yard manure, yet not so early as after the bone-dust prepared with sulphuric acid; yet guano in other respects has the advantage of the prepared bone-dust in producing plants with broader and rougher leaves, better spread, and of a deeper green colour; the guano also in light land maintains the autumnal growth better. Guano has not been long enough in use for its being ascertained how many years its effect continues. I have, however, seen several fields on which turnips were grown after it in the summer of 1842, that produced a decidedly better grain-crop in 1843, and the

our coast much frequented by them, would fertilise.* Some dung of sea birds brought from a rock on the coast of Merionethshire, produced a powerful but transient effect on grass. It was tried, at my request, by Sir Robert Vaughan, at Nannau.

The rains in our climate must tend very much to injure this species of manure, where it is exposed to them, soon after its deposition; but it may probably be found in great perfection in caverns or clefts in rocks, haunted by cormorants and gulls. I examined some recent cormorants' dung, which I found on a rock near Cape Lizard, in Cornwall. It had not at all the appearance of the guano; was of a greyish white colour; had a very fœtid smell like that of putrid animal matter; when acted on by quicklime it gave abundance of ammonia; treated with nitric acid it yielded uric acid.

Night soil, it is well known, is a very powerful manure, and very liable to decompose. It differs in its composition; but always abounds in substances composed of carbon, hydrogen, azote, and oxygen. From the analysis of Berzelius, it appears that a part of it is always soluble in water; and in whatever state it is used, whether recent or fermented, it supplies abundance of food to plants.

The disagreeable smell of night soil may be destroyed by mixing it with quicklime; and if exposed to the atmosphere in thin layers strewed over with quicklime in fine weather, it speedily dries, is easily pulverised, and in this state may be used in the same manner as rape-cake, and delivered into the furrow with the seed.†

sole of clover and rye-grass promises a fine hay-crop in 1844. On poor thin soils in the north, that generally produce very inferior grass and clover, I have seen small doses of guano applied at another part of the rotation with remarkable effect. The rotation commenced with turnips manured with farm-yard dung and bone-dust in the usual way, and the oats or bere that followed, and along with which the grass and clover seeds were sown, was dressed with 2 cwt. of guano per acre, mixed, to aid in the distribution, with twice as much dry sifted earth. The price of the guano was repaid in the increase of grain, again, in the increase of straw, and the succeeding hay-crop has proved remarkably fine—as good in many instances as could have been grown on very fine land.

In the more decomposed guanos, where most of the nitrogen exists as bicarbonate of ammonia, the constituents will be consumed or washed out in a single season, but when the guano is less decomposed, and contains nitrogen in the form of uric acid, it ought to be more permanent. The bone-earth of guano will of course remain in the soil, but being in finer division of parts it will be more serviceable than the same weight in the form of crushed bones.

Guano along with sulphate of magnesia has been used with excellent effect as a manure for potatoes.

* The only instance I am aware of in which the excrements of sea-birds have been collected and employed as manure in this country, is that of the black-capped gull (*Larus ridibundus*). This gull is gregareous, vast numbers of them breeding on some small island in a pond or marsh. The droppings often accumulate on the island and in the marsh to an extent capable of manuring many acres. After rearing their brood the gulls disperse, and the place may then be approached and the droppings collected without risk of the birds deserting the locality. Colonies of these birds occur at intervals in the vicinity of the Scotch coasts, particularly near estuaries or low sandy coasts. The proprietors of the spots occupied by these colonies might turn them to greater account by protecting the birds, and making simple arrangements whereby without materially altering the character of the place, this valuable substance might be preserved from being unnecessarily drenched with water.

† Berzelius's analysis of *fæces*, referred to in the text, is as follows:—

The Chinese, who have more practical knowledge of the use and application of manures than any other people existing, mix their night soil with one-third of its weight of a fat marl, make it into cakes, and dry it by exposure to the sun. These cakes, we are informed by the French missionaries, have no disagreeable smell, and form a common article of commerce of the empire.

The earth, by its absorbent powers, probably prevents, to a certain extent, the action of moisture upon the dung, and likewise defends it from the effects of air.

After night soil, *pigeons' dung* comes next in order, as to fertilising power. I digested 100 grains of pigeons' dung in hot water for some hours, and obtained from it 23 grains of soluble matter, which afforded abundance of carbonate of ammonia by distillation; and left carbonaceous matter, saline matter, principally common salt, and carbonate of lime as a residuum.* Pigeons' dung when moist readily ferments, and after fermentation contains less soluble matter than before; from 100 parts of fermented pigeons' dung, I obtained only eight parts of soluble matter, which gave proportionally less carbonate of ammonia in distillation than recent pigeons' dung.

Water,	73·3
Albumen,	0·9
Bile,	0·9
Mucilage, fat, and other animal matters,	16·7
Saline matter,	1·2
Undecomposed food,	7·0
	100·0

Liebig gives the following ultimate analysis of *fæces* by Playfair:—

Carbon,	45·24
Hydrogen,	6·88
Nitrogen, Oxygen,	34·73
Ashes,	13·15
	100·00
Water,	300·00
	400·00

In Boussingault and Payen's table, there will be found estimates of the nitrogen contained in two different specimens of *poudrette*, or dried and partially decomposed *fæces*. The *poudrette* of Belloni contained, in the dry state, nearly twice as much nitrogen as that of Montfaucon. Good methods of drying and concentrating the night-soil collected in large towns, so as to preserve all the ammonia and useful constituents, and at the same time present it in the form of a dry inodorous powder, are much wanted. Quick-lime cannot be used without great loss; but were the ammonia fixed by sulphuric or muriatic acid, it might be dried by a regulated heat without loss. The only objection to mixing fresh night-soil with peat, saw-dust, or charcoal, is that the increased bulk diminishes the distance to which it will afford to be transported. Near large towns, night-soil is generally mixed in compost with earth, peat, or the less putrescible varieties of farm-yard manure.

* Sprengel found pigeons' dung half a year old to contain 16 per cent. of soluble matter, consisting of very little urea, but of a large proportion of ammoniacal salts, together with common salt and sulphate of potash. The insoluble part consisted chiefly of sand, and phosphates of lime and magnesia.

It is evident that this manure should be applied as new as possible; and when dry, it may be employed in the same manner as the other manures capable of being pulverised.

The soil in woods where great flocks of wood-pigeons roost, is often highly impregnated with their dung, and it cannot be doubted, would form a valuable manure. I have found such soil yield ammonia when distilled with lime. In the winter likewise it usually contains abundance of vegetable matter, the remains of decayed leaves; and the dung tends to bring the vegetable matter into a state of solution.

The dung of *domestic fowls* approaches very nearly in its nature to pigeons' dung. Uric acid has been found in it. It gives carbonate of ammonia by distillation, and immediately yields soluble matter to water. It is very liable to ferment.*

The dung of fowls is employed in common with that of pigeons by tanners to bring on a slight degree of putrefaction in skins that are to be used for making soft leather; for this purpose the dung is diffused through water. In this state it rapidly undergoes putrefaction, and brings on a similar change in the skin. The excrements of dogs are employed by the tanner with similar effects. In all cases, the contents of the *grainer*, as the pit is called in which soft skins are prepared by dung, must form a very useful manure.

Rabbits' dung has never been analysed. It is used with great success as a manure by Mr Fane, who finds it profitable to keep rabbits in such a manner as to preserve their dung. It is laid on as fresh as possible, and is found better the less it has fermented.

The *dung* of *cattle*, *oxen* and *cows*, has been chemically examined by MM. Einhof and Thaer. They found that it contained matter soluble in water; and that it gave in fermentation nearly the same products as vegetable substances, absorbing oxygen and producing carbonic acid gas.†

* It is not much manure of this kind that can occur on a farm, yet what there is should not be neglected. In the recent state it is found to answer better as a dressing for grain, than for green-crops, the latter being somewhat liable to run too much to tops.

† Many analyses of the solid excrements of horses, oxen and cows, have been made since those referred to in the text; those by the method of ultimate analysis, are most satisfactory, and the following deserve especial notice. The first is from Liebig, (Chemistry applied to Agriculture and Physiology, second edition, page 166.) The second and third are by Boussingault, (*Annales de Chimie, T., LXXI, pp.* 122 *et* 134.)

	Solid Excrement of a Cow.	Solid Excrement of a Milch Cow.	Solid Excrement of a Horse.
Carbon,	44·00	42·8	38·7
Hydrogen,	5·84	5·2	5·1
Oxygen,	34·17	37·7	37·7
Nitrogen,	3·59	2·3	2·2
Ashes,	12·40	12·0	16·3
	100·00	100·0	100·0
Water,	609·22	610·3	404·2
	709·22	710·3	504·2

The composition of the solid excrements of cattle varies considerably with the age of the animal, the nature of its food, its condition, temperament, and the amount of labour, exercise, and exposure in the open air, it is subjected to,

The recent *dung* of *sheep*, and of *deer*, afford, when long boiled in water, soluble matters, which equal from two to three per cent. of their weight. I have examined these soluble substances procured by solution and evaporation; they contain a very small quantity of matter analogous to animal mucus; and are principally composed of a bitter extract, soluble both in water and in alcohol. They give ammoniacal fumes by distillation; and appear to differ very little in composition.

I watered some blades of grass for several successive days with a solution of these extracts; they evidently became greener in consequence, and grew more vigorously than grass in other respects, under the same circumstances.

The part of the dung of cattle, sheep, and deer, not soluble in water, appears to be mere woody fibre, and precisely analogous to the residuum of those vegetables that form their food after they have been deprived of all their soluble materials.

The dung of horses gives a brown fluid, which, when evaporated, yields a bitter extract, which affords ammoniacal fumes more copiously than that from the dung of oxen.

If the pure dung of cattle is to be used as manure, like the other species

together with many other circumstances. It is, therefore, only from many analyses of carefully selected specimens of excrements, that satisfactory average results can be obtained. The solid excrement of the horse, probably from containing less water, as well as from its more open and porous texture, undergoes more rapid decomposition than that of oxen and cows, and much more than that of pigs. Hence, horse-dung is called a *hot* manure, and is much employed to mix with the colder and slower fermenting manures and composts.

Apart from the azotised substances, so necessary for nourishing plants, and inducing decomposition on the woody and cellular substances contained by the solid excrements, the ashes or fixed saline and earthy substances are of great importance as food for plants. It is much to be regretted that it formed no part of Boussingault's plan to examine minutely the ash of the various manures and crops analysed by him. On this subject little has hitherto been done. Liebig in his work so frequently quoted, gives the following statement by Dr. Jackson of the composition of the ash of recent horse-dung. The dung was dried at a temperature a little above 212° F. and consisted of:—

Water,	357·0
Matter destructible by ignition,	135·0
Silica,	3·2
Phosphate of lime,	0·4
Carbonate of Lime,	1·5
Phosphate of magnesia and soda,	2·9
	500·0

Dr Fownes, in his valuable essay on the food of plants, recently published by the Royal Agricultural Society of England, gives the following statement of the composition of the ash of horse-dung two years old. 100 parts of the ash consisted of:—

Sulphate of potash,	6·8
Soluble chlorides, with trace of alkaline carbonate,	14·7
Earthy phosphates, oxide of iron, &c.,	34·0
Carbonate of lime,	12·0
Siliceous scales,	32·5
	100·0

of dung which have been mentioned, there seems no reason why it should be made to ferment except in the soil; or if suffered to ferment, it should be only in a very slight degree. The grass in the neighbourhood of recently voided dung, is always coarse and dark green; some persons have attributed this to a noxious quality in unfermented dung; but it seems to be rather the result of an excess of food furnished to the plants.

The question of the proper mode of the application of the dung of horses and cattle, however, properly belongs to the subject of *composite manures*, for it is usually mixed in the farm-yard with straw, offal, chaff, and various kinds of litter; and itself contains a large proportion of fibrous vegetable matter.

A slight incipient fermentation is undoubtedly of use in the dunghill; for by means of it a disposition is brought on in the woody fibre to decay and dissolve, when it is carried to the land, or ploughed into the soil; and woody fibre is always in great excess in the refuse of the farm.

Too great a degree of fermentation is, however, very prejudicial to the composite manure in the dunghill; it is better that there should be no fermentation at all before the manure is used, than that it should be carried too far. This must be obvious from what has been already stated in this Lecture. The excess of fermentation tends to the destruction and dissipation of the most useful part of the manure; and the ultimate results of this process are like those of combustion.

It is a common practice amongst farmers, to suffer the farm-yard dung to ferment till the fibrous texture of the vegetable matter is entirely broken down; and till the manure becomes perfectly cold, and so soft as to be easily cut by the spade.

Independent of the general theoretical views unfavourable to this practice founded upon the nature and composition of vegetable substances, there are many arguments and facts which shew that it is prejudicial to the interests of the farmer.

During the violent fermentation which is necessary for reducing farm-yard manure to the state in which it is called *short muck*, not only a large quantity of fluid, but likewise of gaseous matter is lost; so much so, that the dung is reduced one-half, or two-thirds in weight; and the principal elastic matter disengaged, is carbonic acid with some ammonia; and both these, if retained by the moisture in the soil, as has been stated before, are capable of becoming an useful nourishment of plants.

In October, 1808, I filled a large retort capable of containing three pints of water, with some hot fermenting manure, consisting principally of the litter and dung of cattle; I adapted a small receiver to the retort, and connected the whole with a mercurial pneumatic apparatus, so as to collect the condensible and elastic fluids which might rise from the dung. The receiver soon became lined with dew, and drops began in a few hours to trickle down the sides of it. Elastic fluid likewise was generated; in three days 35 cubical inches had been formed, which, when analysed, were found to contain 21 cubical inches of carbonic acid, the remainder was hydrocarbonate mixed with some azote, probably no more than existed in the common air in the receiver. The fluid matter collected in the receiver at the same time amounted to nearly half an ounce. It had a saline taste, and a disagreeable smell, and contained some acetate and carbonate of ammonia.

Finding such products given off from fermenting litter, I introduced the beak of another retort filled with similar dung very hot at the time, into the soil amongst the roots of some grass in the border of a garden

in less than a week a very distinct effect was produced upon the grass; upon the spot exposed to the influence of the matter disengaged in fermentation, it grew with much more luxuriance than the grass in any other part of the garden.

Besides the dissipation of gaseous matter when fermentation is pushed to the extreme, there is another disadvantage in the loss of *heat*, which, if excited in the soil, is useful in promoting the germination of the seed, and in assisting the plant in the first stage of its growth, when it is most feeble and most liable to disease: and the fermentation of manure in the soil must be particularly favourable to the wheat crop in preserving a genial temperature beneath the surface late in autumn, and during winter.

Again, it is a general principle in chemistry, that in all cases of decomposition, substances combine much more readily at the moment of their disengagement, than after they have been perfectly formed. And in fermentation beneath the soil the fluid matter produced is applied instantly, even whilst it is warm, to the organs of the plant, and consequently is more likely to be efficient, than in manure that has gone through the process; and of which all the principles have entered into new combinations.

In the writings of scientific agriculturists, a great mass of facts may be found in favour of the application of farm-yard dung in a recent state. Mr Young, in the Essay on Manures, which I have already quoted, adduces a number of excellent authorities in support of the plan. Many who doubted, have been lately convinced; and perhaps there is no subject of investigation in which there is such a union of theoretical and practical evidence. I have myself within the last ten years witnessed a number of distinct proofs on the subject. I shall content myself with quoting that which ought to have, and which I am sure will have, the greatest weight amongst agriculturists. Within the last seven years Mr Coke has entirely given up the system formerly adopted on his farm of applying fermented dung; and he informs me, that his crops have been since as good as they ever were, and that his manure goes nearly twice as far.*

* The difference of opinion that exists on this subject has arisen on the one hand from giving too exclusive attention to the state in which farm-yard manure is capable of imparting the greatest amount of nutritive matter to the soil, without considering whether the recent state of the manure answers the other conditions which the practical man must look to; and on the other hand, those who advocate the practice of fermenting the manure, seem often to have overlooked the abstract question of the greatest amount of nutritive matter, as well as the fact, that conditions and circumstances may so vary, that what is good and sound practice in one case may be just the reverse in another. Davy has been supposed by many to lay down an absolute rule, that it is best, in all cases, to employ unfermented manure. A candid perusal of the text, however, will show that he merely lays down the rule, that by ploughing in fresh dung, more nutritive matter is applied to the soil than by first fermenting it; and, consequently, that where there are no special reasons against this mode of application, it is to be adopted.

A good deal of what was said, page 214, on ploughing in dry straw applies to the present question, and need not be repeated. Before deciding whether it is better to employ unfermented manure, the practical man has to consider a number of circumstances, of which the following are examples:—1st, The texture of the soil. If it is stiff and close, recent manure will open and improve it; if it is light and open, the more compact fermented manure will be more appropriate. 2nd, The period at which the manure is required to act. If general

A great objection against slightly fermented dung is, that weeds spring up more luxuriantly where it is applied. If there are seeds carried out in the dung they certainly will germinate; but it is seldom that this can be the case to any extent; and if the land is not cleansed of weeds, any kind of manure fermented or unfermented will occasion their rapid growth. If slightly fermented farm-yard dung is used as a top-dressing for pastures, the long straws and unfermented vegetable matter remaining

enriching of the soil, and an effect on several successive crops is required, recent manure will be more advantageous; but if on the other hand the plants to be cultivated come to maturity in a short time, and require large supplies of food, especially when young, fermented manure will best answer the conditions. 3d, The amount of organic matter present in the soil. If it is admitted that the organic matters in the soil—the remains of former crops and manures—are nutritive, then, whatever, while it decays itself, at the same time promotes their decay, is doubly useful; and accordingly the stiff soils to which unfermented manure has been found most applicable are those that contain at least a fair proportion of organic matter. 4th, The quantity of manure applied. Fermentation is more easily carried on in a large quantity of manure than a small; the necessary temperature is more readily maintained; and fermentation once commenced, will proceed with ease under circumstances in which it would be difficult to commence it. Hence, a large dose of unfermented manure, applied under circumstances otherwise favourable, will succeed, when a small dose would be almost thrown away; and a small dose of manure in which fermentation has been commenced, will often, when properly applied, produce a greater effect than could have been looked for.

By attending to such considerations as these, it is not difficult to decide on what is proper in individual cases, and to shew the accordance of theory with the best practice.

When fermentation is had recourse to, as in general it must, the greatest care should be taken to conduct this process with as little loss as possible. The hot and rapidly fermenting manure from the stable should be equally distributed over the heap as it is produced, that it may be mixed with the wetter and less fermentable manure from the cow-houses and piggeries. Decomposition may be retarded, when necessary, by the compression produced by the treading of cattle, or when carried to the field, by driving the loaded carts over the heap. Loss of ammonia is prevented by covering the sides and top of the heap with peat or earth rich in organic matter, but far more effectually by sprinkling sulphuric or muriatic acid on it from time to time. Dunghills are occasionally roofed over to prevent rain from falling on them, but when the site has been properly constructed, so that all the liquid matter, above what is required for giving the manure the proper texture, is received into tanks, this protection is unnecessary; in no case ought urine or the drainings of a dung-hill to be allowed to run to waste.

For many calculations and comparisons, a knowledge of the composition of well made farm-yard manure is requisite. More analyses are highly desirable, particularly of farm-yard manure prepared according to different methods, the details of which should be fully stated. The analyses given by Boussingault in his paper on the relative value of rotations, (*Annales de Chimie, T., I., p.* 208,) are perhaps the most trustworthy. The manure of Bechelbronn consisted of the excrements of 30 horses, 30 horned cattle, and from 12 to 20 pigs, mixed with the usual amount of litter impregnated with urine. Fermentation was carried on till the mass was half consumed; the straw of the litter was not entirely decomposed, but remained soft and filamentous. To determine the percentage of water, three trials were made; two of manure prepared in different winters, the third of manure prepared in summer. The specimens were first dried in the sun, and then powdered, and dried in vacuo at 230° F. The mean of the three experiments gave 79·3 per cent. of water. To determine the composition of the dry matter, six different analyses were made on specimens of

on the surface should be removed as soon as the grass begins to rise vigorously by raking, and carried back to the dunghill; in this case no manure will be lost, and the husbandry will be at once clean and economical.

In cases when farm-yard dung cannot be immediately applied to crops, the destructive fermentation of it should be prevented as much as possible: the principles on which this may be effected have been already alluded to.

The surface should be defended as much as possible from the oxygen of the atmosphere; a compact marl, or a tenacious clay, offers the best protection against the air; and before the dung is covered over, or as it were, sealed up, it should be dried as much as possible. If the dung is found at any time to heat strongly, it should be turned over, and cooled by exposure to air.

Watering dunghills is sometimes recommended for checking the progress of fermentation; but this practice is inconsistent with just chemical views. It may cool the dung for a short time; but moisture, as I have before stated, is a principal agent in all processes of decomposition. Dry fibrous matter will never ferment. Water is as necessary as air to the process; and to supply it to fermenting dung, is to supply an agent which will hasten its decay.

In all cases when dung is fermenting, there are simple tests by which the rapidity of the process, and consequently the injury done, may be discovered.

If a thermometer plunged into the dung does not rise to above 100 degrees of Fahrenheit, there is little danger of much aeriform matter flying off. If the temperature is higher, the dung should be immediately spread abroad.

When a piece of paper moistened in muriatic acid held over the steams arising from a dunghill gives dense fumes, it is a certain test, that the decomposition is going too far; for this indicates that volatile alkali is disengaged.

When dung is to be preserved for any time, the situation in which it is kept is of importance. It should, if possible, be defended from the sun. To preserve it under sheds would be of great use; or to make the site of a dunghill on the north side of a wall. The floor on which the dung is heaped, should, if possible, be paved with flat stones; and there should be a little inclination from each side towards the centre, in which there should be drains connected with a small well furnished with a pump, by which any fluid matter may be collected for the use of the land. It

manure, some prepared in winter, and some in summer. The mean of these analyses was as follows:—

Carbon,	35·8
Hydrogen,	4·2
Oxygen,	25·8
Nitrogen,	2·0
Ashes,	32·2
	100·0
Water,	383·0
	483·0

This estimate it will be interesting for the reader to compare with those of the solid excrements of cows and horses given in a former note.

too often happens that a dense mucilaginous and extractive fluid is suffered to drain away from the dunghill, so as to be entirely lost to the farm.

Street and *road dung*, and the *sweepings of houses*, may be all regarded as composite manures; the constitution of them is necessarily various, as they are derived from a number of different substances. These manures are usually applied in a proper manner without being fermented.*

* Street sweepings and the other filth and refuse of towns deserve notice, because their removal is essential to the health of the inhabitants. The great bar to their removal is the expense of cleansing the streets, and of collecting and removing the refuse. It can be shewn, however, that when properly mixed, these substances form so valuable a manure, that in most cases it might be sold for a sum more than adequate to cover the expense of thoroughly cleansing the streets. As on this subject little accurate information has been published, it may not, perhaps, be out of place to mention a few particulars regarding the manner in which this manure is managed in Aberdeen; particularly as the method has proved very successful, and has resulted from much care and attention on the part of the Commissioners of Police.

The refuse of towns, or as it is commonly called in Scotland, *police dung*, is a very variable mixture of all kinds of waste matter, such as sweepings of streets, sweepings of houses, coal-ashes and cinders, night-soil, urine, and all kinds of offal and refuse. In Aberdeen, the police act does not entitle the commissioners to claim stable and cow-house dung, nor the blood and offal of the slaughter-houses. Dust-carts proceed along the streets at stated hours and collect all the ashes and house refuse, and at other times to collect the sweepings of the streets, the contents of ash-pits, &c. The street sweepings, the least valuable part, has been found to amount to about one-seventh of the whole matter collected. The refuse is carted to sites at some distance from the town, and to secure as great uniformity as possible, care is taken in emptying the carts, that the most valuable parts be mixed with the street sweepings, and the wettest portions with the driest. The heaps thus formed are sold every week, trenches being cut the day before the sale, to divide the mass into hills of fixed dimensions. Each of these hills contains about seven tons of manure, and the average price for the last three years has been 23s. 4d. per hill. The number of hills sold in 1843 was 2,798, and the average price 23s. ¾d. All the year through, this manure finds purchasers, but as might have been expected, the highest price is obtained during the spring and early summer months. The police dung is let by the commissioners to contractors for a yearly rent, and this rent is always more than sufficient to pay the expense of cleansing the streets. The business of cleansing, however, for the sake of securing efficiency, is not done by contract, but under the superintendence of an officer appointed by the commissioners. On an average of the last four years for which the accounts are published, I find that the annual rent paid for the dung by the contractors, who ultimately sell it to the farmers, (£1,922) exceeds the annual expense of cleansing (£1,297) by £625; and this result is rendered even more satisfactory by two circumstances—1st, That the cleansing is quite efficient, and 2nd, That it has been effected under an act which does not apply to the whole population; the inhabitants of certain suburbs having been hitherto allowed to sell the manure they produce. The population of the town by the last census was 63,262.

Police dung, with all the care that can be taken in mixing, is very variable in its quality. The old and crowded parts of the town, where there are no common sewers, produce the best manure. Hitherto no use has been made of the contents of the sewers, and there are considerable difficulties in the way of rendering them available. The use of police dung is limited to a distance of about nine miles round the town, and were it not that it is taken by the carts which have been delivering grain and other agricultural produce, it would not bear the expense of transport so far. By water carriage it is sent much farther.

Near Aberdeen, police dung is chiefly employed as a manure for turnips. For this purpose it is not used alone, on account of its effect on the succeeding crops

Soot, which is principally formed from the combustion of pit-coal or coal, generally contains likewise substances derived from animal matters. This is a very powerful manure. It affords ammoniacal salts by distillation, and yields to hot water a brown extract, of a bitter taste. It likewise contains an empyreumatic oil. Its great basis is charcoal, in a state in which it is capable of being rendered soluble by the action of oxygen and water. *

of the rotation being inconsiderable, but mixed with farm-yard manure. During the winter and spring, police dung is purchased from time to time and spread uniformly over the farm-yard dung-hill. When a fresh layer of farm-yard dung has accumulated, and been spread over the hill, another layer of police dung is applied, and so on, till within a short time of turnip-sowing, when the whole is turned and applied to the land. This mixture, which always proves short and well fermented, consists of about two parts of farm-yard dung, to one of police dung; and produces excellent crops of turnips—better far than in the same soils can be grown after farm-yard dung alone; and the bulbs are free from the disease called fingers and toes, so liable to be produced by a large dose of farm-yard dung, particularly if it has not been well fermented.

Police dung is not found to answer well as a manure for potatoes, that crop being more dependent on large supplies of food in the latter part of the season. When it is tried, the plants look vigorous and healthy for a time, but always fall of in July, and the yield proves deficient. Although police dung cannot be depended on alone, yet a small addition of it to farm-yard manure is useful in giving the potato plants a start in the beginning of the season.

As a top-dressing to grain-crops, police dung is also extensively used. The best results are got when it is obtained fresh, and immediately spread and harrowed in with the seed. Applied in this way, and with favourable weather to follow, its effect is very remarkable; but when its application is followed by excessive rain, or excessive drought, little or no benefit is derived from it.

On the whole then, police dung is a most important source of special manure to farms near large towns; but to obtain from it the best results it must be applied with skill, and never trusted to *alone* for very permanent effect. From its weight, and the expense of transporting it to a distance, it is probable that its price will be lowered by the increased use of guano, and the dry preparation of bone-dust with sulphuric acid. One useful result of the competition, however, will be, to render those who have to dispose of police dung more careful in using every means of improving its quality, such as more careful mixing to secure uniformity, and the rejection of all waste matters known to be prejudicial to land. Of these, it may be enough to specify one, namely, furnace ashes and slag of all kinds. Coals burnt in the ordinary way afford a light grey-coloured ash, mixed with cinders and small coal, but the ash is not fused. This ash is found to be a remarkably useful though transient manure; but the ash from furnaces, by reason of the great heat and the inferiority of the coals used, is generally more or less fused into slag, and this slag, even when mixed with the most valuable matters, does permanent injury to most soils, and hence it ought to be carefully excluded.

* This is extremely doubtful. Carbon may be very useful in absorbing gases and other substances, and yielding them to the roots of plants, but at ordinary temperatures it is incapable of combining with oxygen. Of the composition of soot little is known. It has not been often examined; and when it has, no attention has been paid to the conditions under which it was formed, such as the kind of coal, the dimensions of the chimney, and the intensity of the heat. In practice it is well known that soot from chimneys where the heat and draught are great, is comparatively worthless as a manure, while that from ordinary chimneys is very valuable. The ammoniacal salts it contains would appear to be its most active principle, for it acts but for a single season, and sometimes so energetically as to deteriorate the succeeding crops. It is more beneficial to potatoes than to turnips, and to grain and grasses than to clover, and other legumenosæ.

This manure is well fitted to be used in the dry state, thrown into the ound with the seed, and requires no preparation.

The doctrine of the proper application of manures from organised sub- ances, offers an illustration of an important part of the economy of ture, and of the happy order in which it is arranged.

The death and decay of animal substances tend to resolve organised rms into chemical constituents; and the pernicious effluvia disengaged the process seem to point out the propriety of burying them in the soil, here they are fitted to become the food of vegetables. The fermentation d putrefaction of organised substances in the free atmosphere are xious processes; beneath the surface of the ground they are salutary erations. In this case the food of plants is prepared where it can be ed; and that which would offend the senses and injure the health, if posed, is converted by gradual processes into forms of beauty and of efulness; the fœtid gas is rendered a constituent of the aroma of the wer, and what might be poison, becomes nourishment to animals and man.

APPENDIX TO LECTURE VI.

[BY THE EDITOR.]

In the notes to the previous Lecture, frequent reference has been made to the Tables of MM. Boussingault and Payen on the composition, comparative values, and equivalents of manures. These Tables appeared in the *Annales de Chimie, et de Physique, 3me., Série,* T., III., p. 65, and T. VI., p. 449, illustrative of two able memoirs on manures. In the following translation some of the columns of less practical utility have been omitted, the two tables have been incorporated into one, and the columns of equivalents have been placed side by side with the columns containing the comparative values of the substances.

The principle on which the various substances are compared is the proportion of nitrogen they contain. Because many saline and earthy substances, containing no nitrogen, are known to exercise a highly fertilising influence on vegetation, some writers, whose attention has been strongly or almost exclusively directed to the importance of the inorganic constituents of soils and manures, have been led not merely to question the accuracy of the principle, but to overlook the very sound and explicit statements of its authors. MM. Boussingault and Payen, while they justly regard the percentage of nitrogen as the best exponent of the value of organic manures, by no means undervalue the inorganic substances they contain; on the contrary, they expressly say of some of them—the animalised blacks, for instance—that they are known to exercise a fertilising influence five times greater than is indicated by their values in the Table. In their memoir they say:—"While recognising the importance, the absolute necessity of azotised principles in manures, we are far from thinking that these principles are the only ones useful in the amelioration of the soil. It is certain that different salts, alkaline and earthy, are indispensable to the development of vegetables." And again, "the mere presence of nitrogen in matter of organic origin is not sufficient to characterise it as a manure; pit coal, for example, contains very appreciable quantities, and nevertheless its ameliorating action on the soil is absolutely nothing as a manure. It is because this substance cannot undergo by the action of atmospheric agents that putrefactive fermentation whose final result is the production of ammoniacal salts and other azotised compounds." MM. Boussingault and Payen hold that the value of manures is proportional to the amount of azotised matter they contain, to the preponderance of the same over their non-azotised organic matter, and that the decomposition of manures of quaternary composition ought to be gradual, keeping pace with the wants of the crops to which they minister.

The Table requires little explanation; the numbers in the two columns entitled VALUES indicate the value of equal weights of the various substances both in their dry and natural undried state, well-made farm-yard manure being assumed as a standard. In the columns entitled EQUIVALENTS, similar standards are adopted, and the equivalent numbers shew the weights of the different substances that in virtue of the nitrogen they contain, ought to be capable of replacing a hundred parts of farm-yard manure, or of producing an equal effect.

TABLE OF THE ANALYSES, COMPARATIVE VALUES, AND EQUIVALENTS OF MANURES.

(Translated from the French of MM. Boussingault and Payen.)

Names of Substances.	Normal Water.	Nitrogen in 100 parts of the substance dried.	Nitrogen in 100 parts of the substance in its normal state.	Values.		Equivalents.		Remarks.
				Substance dried.	Substance in its normal state.	Substance dried.	Substance in its normal state.	
Farm-yard Manure,	79·3	1·95	0·40	100·	100·	100·	100·	
Pea Straw,	8·5	1·95	1·79	100·	447·5	100·	22·3	
Millet Straw,	19·0	0·96	0·78	49·	195·	203·	51·23	
Buckwheat Straw,	11·6	0·54	0·48	27·7	120·	361·1	83·33	
Lentil Straw,	9·2	1·12	1·01	57·4	252·5	174·	39·6	
Wheat Straw,	19·3	0·30	0·24	15·4	60·	650·	166·66	
Do.	5·3	0·53	0·49	27·2	122·5	367·9	81·6	Old 1840, environs of Paris.
Do.	5·3	0·43	0·41	22·	102·5	453 5	97·5	Lower part, 0·67 of the length.
Do.	9·4	1·42	1·33	72·8	332·5	137·3	30·0	Upper part, the threshed ears included, 0·33 of [the length. (1.)
Rye Straw,	12·2	0·20	0·17	10·3	42·5	975·	235·3	
Do.	12·6	0·50	0·42	25·6	105·	390·	95·2	Harvest 1841, environs of Paris.
Oat Straw,	21·0	0·36	0·28	18·5	70·	541·76	142·85	
Barley Straw,	11·0	0·26	0·23	13·3	57·5	750·	173·9	
Chaff of Wheat,	7·6	0·94	0·85	48·	212·5	207·4	47·	
Dried Stems of Jerusalem Artichokes,	12·9	0·43	0·37	22·	92·5	453·5	108·1	
Stems of Madia,	14·3	0·66	0·57	33·8	142·5	295·45	70·17	
Madia sativa, green,	70·55	1·534	0·45	78·6	112·5	127·1	88·8	Roots, stems, leaves and flowers.
Grass of a Natural Meadow,	87·5	4·29	0·53	220·	132·5	45·45	75·47	Grasses.
Broom,	10·4	1·37	1·22	70·3	305·	142·3	32·78	Stems and leaves.
Leaves of Beet-root, green,	88·9	4·50	0·50	230·8	125·	43·3	80·	
Potato Halm,	76·0	2·30	0·55	117·9	137·5	84·78	72·72	At Harvest.
Leaves of Carrots,	70·9	2·94	0·85	150·8	212·5	66·3	47·	
Leaves of Heath,	7·0	1·90	1·74	97·4	435·	102·6	22·9	Dried in the air.
Branches and Leaves of Box,	59·26	2·89	1·17	148·2	292·5	67·5	34·19	
Autumnal Leaves of Oak,	24·99	1·565	1·175	80·3	293·8	124·6	34·04	
..... Beech,	39·3	1·906	1·177	97·7	294·3	102·3	33·98	
..... Poplar,	51·1	1·166	0·538	59·8	134·5	167·2	74·35	
..... Acacia,	53·6	1·557	0·721	79·8	180·3	125·2	55·48	
..... Pear Tree,	14·5	1·53	1·36	78·5	340·	127·4	29.41	

(1.) These lengths bear to each other the ratio of 93 to 23 by weight.

Names of Substances.	Normal Water.	Nitrogen in 100 parts of the substance dried.	Nitrogen in 100 parts of the substance in its normal state.	Values.		Equivalents.		Remarks.
				Substance dried.	Substance in its normal state.	Substance dried.	Substance in its normal state.	
Kelp,	3·8	0·40	0·38	20·5	95·	487·5	105·26	
Fucus Digitatus,	39·2	1·41	0·86	72·3	215·	138·29	46·5	
Do. Do.	40·0	1·58	0·95	81·	237·5	123·4	42·1	
Do. Saccharinus,	40·0	2·29	1·38	117·4	345·	85·2	28·9	Dried in the air.
Do. Do.	75·5	"	0·54	"	135·	"	74·07	Fresh from the sea.
Brewers' Grains,	6·0	4·90	4·51	251·3	1127·5	39·7	8·8	
Roots of Clover,	9·7	1·77	1·61	90·8	402·5	110·16	24·84	The roots dried in the air.
Cake of Linseed,	13·4	6·00	5·20	307·7	1300·	32·5	7·69	
..... Colza,	10·5	5·50	4·92	282·	1230·	35·45	8·13	
..... Arachis hypogea,	6·6	8·89	8·33	455·9	2082·5	21·93	4·8	
..... Madia sativa,	11·2	5·70	5·06	292·3	1265·	34·2	7·9	
..... Seeds of Cotton,	11·02	4·524	4·02	232·	1005·	43·1	9·95	
..... Camelina,	6·5	5 93	5·515	304·1	1378·75	32·8	7·25	
..... Hemp,	5·0	4·78	4 21	245·1	1052·25	40·8	9·50	
..... Poppies,	6·0	5·70	5·36	292·3	1340·	34·2	7·46	
..... Beech,	6·2	3·53	3·31	181·	827·5	55·2	12·08	A very woody cake employed as fuel.
..... of Nuts,	6·0	5·59	5·24	286·6	1310·	34·8	7·63	
..... Refinement,	10·0	3·92	3·54	201·	885·	49·7	11·29	From green fats, with saw-dust of poplar.
..... Do.	7·67	0·58	0·54	29·7	135·	361·1	74·07	From fish oil, with poplar saw-dust.
Seeds of White Lupin,	10.5	4·35	3·49	223·1	872·5	44·8	11·46	Boiled and dried, Tuscan.
Grounds of Cyder Apples,	6·4	0·63	0·59	32·3	147·5	309·5	67·79	(1841). Previously dried.
Grounds of Hops,	73·05	2·228	0·60	114·3	150·	87·6	66·6	German hops of the finest quality.
Scum of Clarification,	67·0	1·579	0·535	80·9	133·8	123·4	74·77	Vigneux, (M. Dombasle's process.)
Refuse of Grapes,	48·2	3·31	1·71	169·7	427·5	58·9	23·39	
Do. Do.	"	3·56	1·83	182·6	457·5	54·77	21·85	
Slices of exhausted Beet-root,	94·5	1·758	0·009	90·2	2·25	110·9	4444·4	Of beet-root macerated. Vigneux. (M. Dombasle's process.)
Pulp of Beet-root,	9·3	1·26	1·14	64·1	285·	154·7	35·08	Dried in the air.
Do. Do.	70·0	"	0·378	64·1	85·	"	105·8	As it leaves the press.
Pulp of Potatoes,	73·0	1·95	0·526	100·	131·5	100·	76 09	Pressed.
Juice of Potatoes,	95·4	8·28	0·376	424·6	94·5	23·5	106·38	Allowed to settle for 4 hours and then decanted.
Waters from Starch Manufactories,	99·15	8·28	0·070	424·6	17·5	23·5	571·42	Wash of 4 volumes of water.
Do. Do. Do.	99·25	8·28	0·062	424·6	15·5	23·5	645·16	Wash of 5 volumes of water.

NAMES OF SUBSTANCES.	Water.	the substance dried.	the substance in its normal state.	Substance dried.	Substance in its normal state.	Substance dried.	Substance in its normal state.	REMARKS.
Deposits of the Waters of Starcheries,	80·0	1·81	0·36	92·8	90·	107·7	111·1	Drained in heaps.
Do. Do. Do.	15·0	1·81	1·538	92·8	384·5	107·7	26·0	Dried in the air.
Saw Dust of Acacia Wood, . .	25·0	0·38	0·29	19·5	72·5	513·2	137·9	Dried in the air.
Do. Do. Do. . .	25·0	0·31	0·23	15·9	57·5	629·0	173·9	Ditto.
Saw Dust of Fir Wood, . .	24·0	0·22	0·16	11·3	40·	886·4	250·	Ditto.
Do. Do. . . .	24·0	0·31	0·23	15·9	57·5	629·	173·9	Ditto.
Saw Dust of Oak, . . .	26·0	0·72	0·54	36·9	135·	256·9	74·	Ditto.
Solid Excrements of Cows, . .	85·9	2·30	0·32	117·9	80·	84·78	125·	
Urine of Cows, ...	88·3	3·80	0·44	194·9	110·	51·3	90·9	
Mixed Excrements of Cows, . .	84·3	2·59	0·41	132·8	102·5	75·28	97·56	Result calculated.
Solid Excrements of Horses, . .	75·3	2·21	0·55	113·3	137·5	88·2	72·7	
Urine of Horse, ...	79·1	12·50	2·61	641·	652·5	15·6	15·3	The Horse drank very little: urine very thick.
Mixed Excrements of Horses, .	75·4	3·02	0·74	154·9	185·	64·56	54·	
Excrements of Swine, . . .	81·4	3·37	0·63	172·8	157·5	57·86	63·4	
Do. of Sheep, . . .	63·0	2·99	1·11	153·3	277·5	65·2	36·	
Do. of Goats, . . .	46·0	3·93	2·16	201·5	540·	49·6	18·5	
Mould, ...	"	1·03	"	52·8	"	189·	"	[sifted to remove the straw. Of Horses dung, in the dry state, and previously
Pigeons' Dung, ...	9·6	9·02	8·30	462·6	2075·	21·4	4·8	From Bechelbronn.
Guano imported into England, .	19·56	6·201	4·988	318·	1247·	31·4	8·02	In the normal state.
Do. purified by Sifting, . .	23·40	7·047	5·398	361·4	1349·5	26·3	7·41	Globular concretions removed by sifting.
Do. imported into France, .	11·28	15·732	13·950	806·8	3487·5	12·4	2·87	Decided putrid odour.
Cockchafers, ...	77·0	13·931	3·204	714·4	801·	13·99	12·48	
Litter of Silk-worms, 5th age, .	14·29	3·483	3·285	178·6	821·3	56·0	12·18	Silk-worm Establishments of Neuilly.
Do. Do. 6th age, .	11·39	3 709	3·290	190·2	822·5	52·6	12·16	Ditto, Ditto.
Chrysalides of Silk Worms, . .	78·50	8·987	1·942	460·5	485·5	21·6	20·60	Establishments of Sénart.
Liquid Flemish Manure, . .	"	"	0·19	"	47·5	"	210·5	Analysed in its normal state.
Do. Do. . .	"	"	0·22	"	55·	"	181·8	Ditto, Ditto.
Water of Dung-hills, . . .	99·6	1·54	0·059	78·9	14·75	126·6	677·9	Washings, the rain of a year.
Urine of the Public Urinals, .	9·57	17·556	16·853	900·3	4213·25	11·1	2·37	Dried in the stove.
Do. Do. Do. . .	96·889	23·108	0·715	1185·	178·8	8·4	55·94	Ammonia included.
Dung of the Inns of the South, .	60·58	2·083	0·79	106·8	197·5	93·6	50·63	Communicated by M. de Gasparin.
Poudrette of Belloni, . . .	12·5	4·40	3·85	225·6	962·5	44·3	10·3	Dried in the air.
Do. of Montfaucon, . .	41·4	2·67	1·56	136·9	390·	73·	25·6	As sent out to Agriculturists.
Black of Refineries, (Mayenne) .	27·65	1·901	1·375	97·5	343·8	102·5	29·09	

NAMES OF SUBSTANCES.	Normal Water.	Nitrogen in 100 parts of the substance dried.	Nitrogen in 100 parts of the substance in its normal state.	VALUES.		EQUIVALENTS.		REMARKS.
				Substance dried.	Substance in its normal state.	Substance dried.	Substance in its normal state.	
Dutch Manure,	44·12	2·478	1·36	127·1	340·	78·6	29·40	Animalised black of Lyons.
English Black,	13·45	8·022	6·952	411·4	1738·	24·3	5·75	Lime, blood, and coal soot.
Animal Black of Refineries,	47·7	2·04	1·06	104·6	265·	95·58	37·73	As sent out.
Animalised Black,	44·6	1·96	1·090	100·5	272·5	98·49	36·69	Prepared 11 months.
Black used in disinfecting common sewers and cess-pools,	42·0	2·958	1·242	151·7	310·5	65·9	32·2	Recently manufactured.
Soot from Coals,	15·6	1·59	1·35	81·5	337·5	122·64	29·62	
Soot from Wood,	5·6	1·31	1·15	67·2	287·5	148·85	34·78	
Dry Flesh, (muscle,)	8·5	14·25	13·04	730·8	3260·	13·68	3·06	Dried in the air.
Salted Codfish,	38·0	10·862	6·70	557·	1675·	17·95	5·97	Water and Salt.
Do. washed and pressed,	10·0	18·74	16·86	961·	4215·	10·40	2·37	Dried in the air.
Blood dried, soluble,	21·43	15·503	12·18	795·	3045·	12·57	3·28	As sent out.
Do. liquid,	81·01	"	2·945	795·	736·3	"	13·58	From the slaughter-houses.
Do. Do.	82·5	"	2·712	795·	678·	"	14·74	Of old horses.
Do. coagulated and pressed,	73·45	17·	4·514	871·8	1128·5	11·47	8·86	As it leaves the press.
Do. dried, insoluble,	12·5	17·	14·875	871·8	3718·8	11·47	2·69	Dried on the large scale.
Feathers,	12·9	17·61	15·34	903·1	3835·	11·07	2·60	
Hair of Oxen,	8·9	15·12	13·78	775·4	3445·	12·89	2·9	
Woollen Rags,	11·28	20·26	17·978	1038·9	4494·5	9·62	2·22	
Raspings of Horn,	9·0	15·78	14·36	809·2	3590·	12·35	2·78	
Bones after digestion, at about 230° F.	7·49	7·58	7·016	388·7	1754·	25·72	5·70	Dried in the air.
Do. Do. humid,	30·0	"	5·306	"	1326·5	"	7·54	As sent out by the boilers.
Bones, undigested,	8·0	"	6·215	"	1553·8	"	6·43	Containing 0·10 of fat.
Refuse of Bone Glue,	42·0	0·912	0·528	46·8	132·	213·8	75·75	
Refuse of Glue,	33·61	5·625	3·734	288·5	933·5	34·6	10·71	As sent out by the manufacturers.
Tallow Melter's waste,	8·18	12·934	11·875	663·2	2968·75	15·07	3·36	
Refuse of Prussian Blue, blood,	53·40	2·8031	1·306	143·7	326·5	69·5	30·63	
Animalised Marine Plants,	12·54	2·756	2·408	143·9	602·	71·1	16·61	Dried in the stove.
Do. Do.	11·72	2·714	2·395	139·2	598·8	71·8	16·70	Ditto.
Oyster Shells,	17·9	0·40	0·32	20·5	80·	487·5	125·	
Sea Shells,	"	0·052	0·052	2·6	13·	3750·	769·23	Previously dried. From the shores of Dunkirk.
Silt of the River Morlaix,	3·7	0·42	0·40	21·5	100·	464·28	100·	
Shell sand from the Roads of Roscoff,	0·5	0·14	0·13	7·2	32·5	1392·85	307·69	
Marl,	1·038	0·517	0·512	26·5	128·	377·17	78·1	[disintegrated pyritic schist.
Ashes of Picardy,	9·2	0·71	0·65	36·4	162·5	274·64	61·5	A black earthy substance, formed chiefly of

The real effect of these three, is five times as great as is indicated by the values or Equivalents.

Tables such as these are useful in enabling practical men to compare one manure with another, and to determine the dose of a manure they have had no experience in using; yet it must be remarked, that in the case of highly azotized and rapidly decomposing manures, such as guano, the theoretical equivalent is liable to be considerably greater than in practice is found necessary.

By calculations so easy and obvious as to require no explanation, this important Table may be extended and corrected as good ultimate analyses of manures accumulate.

Supplemental Note on Guano.—Since the note, page 232 was written, I have had occasion to examine samples of some recently imported cargoes of guano, both from South America and Africa. The African samples I have seen are very different from the Peruvian and Bolivian both in physical characters and chemical composition. In the African the density is considerably less, the hard lumps are nearly absent, and in many samples, especially those that are pretty dry, small silky crystals of oxalate of ammonia abound. In the South American guanos uric acid is often present in considerable quantity, but in the African samples, I have met with but mere traces of it, and in its place ulmic and humic acids. In examining guanos for agricultural purposes, the method I have followed is to make separate estimates of the water, ammonia, uric acid, and the ulmic and humic acids when present; to estimate the remaining organic matter, oxalic acid &c., by loss on ignition at a low red heat; and to estimate the fixed alkaline salts, the earthy salts, and the foreign matters out of the ash.

The following table contains the results of six different analyses.—No. I., from South America, was a dry cream-coloured sample, totally different in appearance from any other sample I have seen, but agreeing with the descriptions of recent white guano said by authors to be so much valued in Peru. The remarkable point about this guano is its freshness; the nitrogen existing principally as uric acid—indeed, in this respect, it does not differ widely from the dried liquid excrement of the sea-eagle as estimated by Coindet. This sample contained a considerable quantity of feathers of sea-birds, and many of the larger and whiter masses had all the appearance of having been formed from fluid matter deposited in successive layers and quickly dried on the bare rocks, angular fragments of which still adhered to the lower part of the cakes, as if considerable force had been required to detach them. It will not escape notice that the quantity of nitrogen contained in the uric acid and ammonia of this sample is almost identical with that contained in the sample obtained by MM. Boussingault and Payen through the French Minister of Agriculture. No. II. was a light brown sample considerably damper, but from the same cargo. No. III. was a fine sample of the lighter brown Peruvian sorts. No. IV. was a drier and darker Peruvian sample. No. V. was a sample of African guano, *ex Commerce*, from Ichaboe, rather light in colour, of less density than the former samples, and shewing, under the lens, numerous minute crystals of oxalate of ammonia. No. VI. was an African sample from Possession Island, darker, damper, and denser than the former, readily parting with a portion of its water in a dry atmosphere, and assuming a light grey colour, with a glistening appearance under the lens. This cargo must have been collected close to water mark, for it contained numerous fronds of sea-weed; bones of birds, and tufts of seals' hair were also found in it:—

ANALYSES OF GUANO.

	I.	II.	III.	IV.	V.	VI.
1st.—*Volatile and Organic Matter.*						
Water,	6·40	11·00	20·54	13·60	25·60	30·80
Ammonia,	2·71	2·69	6·92	5·83	9·83	5·95
Uric Acid,	34·70	21·35	11·70	2·30	—	—
Ulmic and humic acids,	—	—	—	—	2·00	3·60
Organic matter, oxalic acid, &c.,	26·79	30·76	28·04	41·07	34·97	23·25
2d.—*Fixed Alkaline Salts.*						
Sulphate of Soda.	2·94	1·65	2·90	5·87	3·98	1·84
Chloride of Sodium,	·86	4·05	·30	1·31	·16	2·45
Alkaline Phosphates,	·48	·58		4·02	1·46	2·61
3rd.—*Earthy Salts.*						
Carbonate of Lime,	1·36	—	—	—	—	trace.
Phosphates of lime and magnesia,	19·24	21·32	28·00	24·08	21·20	17·96
4th.—*Foreign Matters.*						
Siliceous grit and sand,	4·52	6·60	1·60	1·92	·80	11·54
	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen in the ammonia and uric acid,	13·81	9·23	8·09	5·58	8·11	4·91

From the foregoing table, it would appear that the African guanos are more decomposed than most of those from South America. If this prove to be always, or generally the case, it will become a matter of the greatest importance to ascertain whether the fresh guanos are decidedly more permanent in their effect than the decomposed ones, for if so, the two kinds, to be used most economically, would require to be applied at very different periods of the ordinary rotations, and perhaps to different crops. My own experiments distinctly point to the conclusion that the fresher guanos are decidedly more permanent, and are most economically employed as a dressing to green crops, to be followed by winter wheat, or perhaps still more so to grain crops, sown down with grass and clover seeds; while the guanos that contain their nitrogen as ready-formed ammonia are best applied to dress grain crops after lea, annual grass, or green forage crops. It is obvious, however, that the introduction of the African guanos, some of which, at least, containing so much ammonia and so little uric acid, will afford better means than we have hitherto possessed of settling this important practical point.

LECTURE VII.

ON MANURES OF MINERAL ORIGIN, OR FOSSIL MANURES; THEIR PREPARATION, AND THE MANNER IN WHICH THEY ACT.—OF LIME IN ITS DIFFERENT STATES; OPERATION OF LIME AS A MANURE AND A CEMENT; DIFFERENT COMBINATIONS OF LIME.—OF GYPSUM; IDEAS RESPECTING ITS USE.—OF OTHER NEUTRO-SALINE COMPOUNDS, EMPLOYED AS MANURES.—OF ALKALIES AND ALKALINE SALTS; OF COMMON SALT.

THE whole tenor of the preceding Lectures shews, that a great variety of substances contributes to the growth of plants, and supplies the materials of their nourishment. The conversion of matter that has belonged to living structures into organised forms, is a process that can be easily understood; but it is more difficult to follow those operations by which earthy and saline matters are consolidated in the fibre of plants, and by which they are made subservient to their functions. Some enquirers adopting that sublime generalisation of the ancient philosophers, that matter is the same in essence, and that the different substances considered as elements by chemists, are merely different arrangements of the same indestructible particles, have endeavoured to prove, that all the varieties of the principles found in plants, may be formed from the substances in the atmosphere; and that vegetable life is a process in which bodies that the analytical philosopher is unable to change or to form, are constantly composed and decomposed. These opinions have not been advanced merely as hypotheses; attempts have been made to support them by experiments. M. Schrader and M. Braconnot, from a series of distinct investigations, have arrived at the same conclusions. They state that different seeds sown in fine sand, sulphur, and metallic oxides, and supplied only with atmospherical air and water, produced healthy plants, which by analysis yielded various earthy and saline matters, which either were not contained in the seeds, or the material in which they grew; or which were contained only in much smaller quantities in the seeds: and hence they conclude that they must have been formed from air or water, in consequence of the agencies of the living organs of the plant.

The researches of these two gentlemen were conducted with much ingenuity and address; but there were circumstances which interfered with their results, which they could not have known, as at the time their labours were published they had not been investigated.

I have found that common distilled water is far from being free from saline impregnations. In analysing it by voltaic electricity, I procured

from it alkalies and earths; and many of the combinations of metals with chlorine are extremely volatile substances. When distilled water is supplied in an unlimited manner to plants, it may furnish to them a number of different substances, which though in quantities scarcely perceptible in the water may accumulate in the plant, which probably perspires only absolutely pure water.

In 1801, I made an experiment on the growth of oats, supplied with a limited quantity of distilled water in a soil composed of pure carbonate of lime. The soil and the water were placed in a vessel of iron, which was included in a large jar, connected with the free atmosphere by a tube, so curved as to prevent the possiblity of any dust, or fluid, or solid matter from entering into the jar. My object was to ascertain whether any siliceous earth would be formed in the process of vegetation; but the oats grew very feebly, and began to be yellow before any flowers formed: the entire plants were burnt, and their ashes compared with those from an equal number of grains of oat. Less siliceous earth was given by the plants than by the grains; but their ashes yielded much more carbonate of lime. That there was less siliceous earth I attribute to the circumstance of the husk of the oat being thrown off in germination; and this is the part which most abounds in silica. Healthy green oats taken from a growing crop, in a field of which the soil was a fine sand, yielded siliceous earth in a much greater proportion than an equal weight of the corn artificially raised.

The general results of this experiment are very much opposed to the idea of the composition of the earths, by plants, from any of the elements found in the atmosphere, or in water; and there are other facts contradictory to the idea. Jaquin states that the ashes of Glass Wort *(Salsola Soda)*, when it grows in inland situations, afford the vegetable alkali; when it grows on the sea-shore where compounds which afford the fossil or marine alkali are more abundant, it yields that substance. Du Hamel found, that plants which usually grow on the sea shore, made small progress when planted in soils containing little common salt. The sunflower, when growing in lands containing no nitre, does not afford that substance; though when watered by a solution of nitre, it yields nitre abundantly. The tables of de Saussure, referred to in the Third Lecture, shew that the ashes of plants are similar in constitution to the soils in which they have vegetated.

De Saussure made plants grow in solutions of different salts, and he ascertained, that in all cases, certain portions of the salts were absorbed by the plant, and found unaltered in their organs. Even animals do not appear to possess the power of forming the alkaline and earthy substances. Dr. Fordyce found, that when canary birds at the time they were laying eggs were deprived of access to carbonate of lime, their eggs had soft shells; and if there is any process for which nature may be conceived most likely to supply resources of this kind, it is that connected with the reproduction of the species.

As the evidence on the subject now stands, it seems fair to conclude, that the different earths and saline substances found in the organs of plants, are supplied by the soils in which they grow; and in no cases composed by new arrangements of the elements in air or water. What may be our ultimate view of the laws of chemistry, or how far our ideas of elementary principles may be simplified, it is impossible to say. We can only reason from facts. We cannot imitate the powers of composition belonging to vegetable structures; but at least we can understand them: and as far as our researches have gone, it appears that in vegetation compound forms are uniformly produced from simpler ones; and the elements in the soil,

the atmosphere, and the earth, absorbed and made parts of beautiful and diversified structures.

The views which have been just developed lead to correct ideas of the operation of those manures which are not necessarily the result of decayed organized bodies, and which are not composed of different proportions of carbon, hydrogen, oxygen, and azote.—They must produce their effect, either by becoming a constituent part of the plant, or by acting upon its more essential food, so as to render it more fitted for the purposes of vegetable life.

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

The only alkaline earths which have been hitherto applied in this way, are lime and magnesia. Potassa and soda, the two fixed alkalies, are both used in certain of their chemical compounds. I shall state in succession such facts as have come to my knowledge respecting each of these bodies in their applications to the purposes of agriculture; but I shall enlarge most upon the subject of lime; and if I should enter into some details which may be tedious and minute, I trust, my excuse will be found in the importance of the enquiry; and it is one which has been greatly elucidated by late discoveries.

The most common form in which lime is found on the surface of the earth, is in a state of combination with carbonic acid or fixed air. If a piece of limestone, or chalk, be thrown into a fluid acid, there will be an effervescence. This is owing to the escape of the carbonic acid gas. The lime becomes dissolved in the liquor.

When limestone is strongly heated, the carbonic acid gas is expelled, and then nothing remains but the pure alkaline earth; in this case there is a loss of weight; and if the fire has been very high, it approaches to one-half the weight of the stone; but in common cases limestones, if well dried before burning, do not lose much more than from 35 to 40 per cent., or from seven to eight parts out of 20.

I mentioned in discussing the agencies of the atmosphere upon vegetables, in the beginning of the Fifth Lecture, that air always contains carbonic acid gas, and that lime is precipitated from water by this substance. When burnt lime is exposed to the atmosphere, in a certain time it becomes mild, and is the same substance as that precipitated from lime water; it is combined with carbonic acid gas. Quicklime, when first made, is caustic and burning to the tongue, renders vegetable blues green, and is soluble in water; but when combined with carbonic acid it loses all these properties, its solubility and its taste: it regains its power of effervescing, and becomes the same chemical substance as chalk or limestone.

Very few limestones or chalks consist entirely of lime and carbonic acid. The statuary marbles, or certain of the rhomboidal spars, are almost the only pure species; and the different properties of limestones, both as manures and cements, depend upon the nature of the ingredients mixed in the limestone; for the true calcareous element, the carbonate of lime, is uniformly the same in nature, properties, and effects, and consists of one proportion of carbonic acid 41·4, and one of lime 55. *

When a limestone does not copiously effervesce in acids, and is sufficiently hard to scratch glass, it contains siliceous, and probably aluminous earth. When it is deep brown or red, or strongly coloured of any of the

* Of carbonic acid 22·12, and lime 28·5.

shades of brown or yellow, it contains oxide of iron. When it is not sufficiently hard to scratch glass, but effervesces slowly, and makes the acid in which it effervesces milky, it contains magnesia. And when it is black and emits a fetid smell if rubbed, it contains coaly or bituminous matter.

The analysis of limestones is not a difficult matter; and the proportions of their constituent parts may be easily ascertained, by the processes described in the Lecture on the Analysis of soils; and usually with sufficient accuracy for all the purposes of the farmer, by the fifth process. *

Before any opinion can be formed of the manner in which the different ingredients in limestones modify their properties, it will be necessary to consider the operation of the pure calcareous element as a manure and as a cement.

Quicklime in its pure state, whether in powder or dissolved in water, is injurious to plants.—I have in several instances killed grass by watering it with lime water.—But lime in its state of combination with carbonic acid, as is evident from the analyses given in the Fourth Lecture, is a useful ingredient in soils. Calcareous earth is found in the ashes of the greater number of plants; and exposed to the air, lime cannot long continue caustic, for the reasons that were just now assigned; but soon becomes united to carbonic acid.

When newly burnt lime is exposed to air, it soon falls into powder; in this case it is called slaked lime, and the same effect is immediately produced by throwing water upon it, when it heats violently, and the water disappears.

Slaked lime is merely a combination of lime, with about one-third of its weight of water; *i. e.* 55 parts of lime absorb 17 parts of water; † and in this case it is composed of a definite proportion of lime to a definite proportion of water, and is called by chemists *hydrate of lime;* and when hydrate of lime becomes carbonate of lime by long exposure to air, the water is expelled, and the carbonic acid gas takes its place.

When lime, whether freshly burnt or slaked, is mixed with any moist fibrous vegetable matter, there is a strong action between the lime and the vegetable matter, and they form a kind of compost together, of which a part is usually soluble in water.

By this kind of operation, lime renders matter which was before comparatively inert, nutritive; and as charcoal and oxygen abound in all vegetable matters, it becomes at the same time converted into carbonate of lime.

Mild lime, powdered limestone, marls or chalk, have no action of this kind upon vegetable matter; by their action they prevent the too rapid decomposition of substances already dissolved; but they have no tendency to form soluble matters.

It is obvious from these circumstances, that the operation of quicklime, and marl or chalk, depends upon principles altogether different. Quicklime in being applied to land tends to bring any hard vegetable matter that it contains into a state of more rapid decomposition and solution, so as to render it a proper food for plants.—Chalk and marl, or carbonate of lime will only improve the texture of the soil, or its relation to absorption; it acts merely as one of its earthy ingredients.—Quicklime, when it be-

* See also appendix to Lecture IV.

† Hydrate of lime consists of 28·5 parts of lime, and 9 of water.

comes mild, operates in the same manner as chalk; but in the act of becoming mild, it prepares soluble out of insoluble matter.

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

The solution of the question whether quicklime ought to be applied to a soil, depends upon the quantity of inert vegetable matter that it contains. The solution of the question whether marl, mild lime, or powdered limestone ought to be applied, depends upon the quantity of calcareous matter already in the soil. All soils which do not effervesce with acids are improved by mild lime, and ultimately by quicklime; and sands more than clays.

When a soil deficient in calcareous matter contains much *soluble* vegetable manure, the application of quicklime should always be avoided, as it either tends to decompose the soluble matters by uniting to their carbon and oxygen so as to become mild lime, or it combines with the soluble matters, and forms compounds, having less attraction for water than the pure vegetable substance.

The case is the same with respect to most animal manures; but the operation of the lime is different in different cases, and depends upon the nature of the animal matter. Lime forms a kind of insoluble soap with oily matters, and then gradually decomposes them by separating from them oxygen and carbon. It combines likewise with the animal acids; and probably assists their decomposition by abstracting carbonaceous matter from them combined with oxygen; and consequently it must render them less nutritive. It tends to diminish likewise the nutritive powers of albumen from the same causes; and always destroys, to a certain extent, the efficacy of animal manures, either by combining with certain of their elements, or by giving to them new arrangements. Lime should never be applied with animal manures, unless they are too rich, or for the purpose of preventing noxious effluvia, as in certain cases mentioned in the last Lecture. It is injurious when mixed with any common dung, and tends to render the extractive matter insoluble.

I made an experiment on this subject: I mixed a quantity of the brown soluble extract, which was procured from sheeps' dung, with five times its weight of quicklime. I then moistened them with water; the mixture heated very much; it was suffered to remain for 14 hours, and was then acted on by six or seven times its bulk of pure water: the water, after being passed through a filter was evaporated to dryness; the solid matter obtained was scarcely coloured, and was lime mixed with a little saline matter.

In those cases in which fermentation is useful to produce nutriment from vegetable substances, lime is always efficacious. I mixed some moist tanner's spent bark with one-fifth of its weight of quicklime, and suffered them to remain together in a close vessel for three months; the lime had become coloured and was effervescent: when water was boiled upon the mixture it gained a tint of fawn colour, and by evaporation furnished a fawn-coloured powder, which must have consisted of lime united to vegetable matter, for it burnt when strongly heated and left a residuum of mild lime. *

* The views entertained of the manner in which lime acts as a manure, have to a great extent, been regulated by the opinions held regarding the sources from

The limestones containing alumina and silica are less fitted for the purposes of manure than pure limestones; but the lime formed from them has no noxious quality. Such stones are less efficacious, merely because they furnish a smaller quantity of quicklime.

which plants derive their carbon. Those who hold that plants receive a great part of their carbon in the form of humic and ulmic acids, extractive matter, &c., also maintain, that a principal function of lime is to unite with organic acids in the soil, and by imparting to them solubility, to render them available to plants, supplying the roots at once with organic matter capable of assimilation, and with lime. In the previous notes, a decided preference has been given to the theory that regards carbonic acid as the only source from which plants directly derive their carbon. If this is correct, and if, as there is every reason to believe, humic and ulmic acids are incapable of being assimilated by plants, the function of lime above stated becomes a matter of much less importance. When slaked lime is added to a soil containing free ulmic and humic acids, it, no doubt, unites with them, and plants may imbibe portions of the soluble compounds thus formed, but it requires to be shewn that they are capable of assimilating the substances thus introduced. Again, when lime is applied to such soils its beneficial influence is not so apparent on the first crop after its application as on the succeeding ones, a circumstance of itself sufficient to cast doubt on this explanation of its mode of action. Lime like all alkaline substances, when present in moderate quantity, promotes decomposition in organic bodies. The precise way in which it does so deserves more accurate investigation than has yet been bestowed upon it; nevertheless, it is well known that when added to soils or composts, it facilitates decay. This decay implies the formation and liberation of carbonic acid which we know to be capable of being absorbed and assimilated by plants. The principal function of lime then, as a manure, appears to be to regulate the condition of the organic matter in the soil, and to facilitate its healthy decay. In nitre beds lime appears to act both by evolving the ammonia that arises from the decay of azotised matter in the mixture, and by facilitating its conversion into nitric acid. What is ascertained to take place in nitre beds can scarcely be supposed not to take place in the soil, where all the circumstances are so similar. Lime is found in the ashes of all plants, and it occurs in all fertile soils. It may, in some cases, be taken up by plants in combination with organic acids, but in well cultivated soils, of proper texture, and in good condition, where humic and ulmic acids can scarcely be said to exist, it must be principally as soluble bicarbonate that it finds its way into their tissues.

Lime that has fallen to powder by exposure to the air consists of a mixture of carbonate and hydrate of lime, the relative proportions of these compounds varying according to the degree to which it has been exposed. It takes a very long exposure of this powder to convert the whole hydrate back again to its original state of carbonate. In the soil, and especially in the presence of much organic matter, the acquisition of carbonic acid is more rapid, yet it is a considerable time before the whole of the hydrate is changed; to this extent then, it is more capable of discharging alkaline functions, is more soluble, and more active in promoting decay of organic matter than has often been supposed. Marl, shell-sand, and calcareous grit, while they are excellent textural ingredients in soils, possess the same sort of action as lime in regulating the decay of organic matter in soils, but in a proportionally less degree as their lime is in combination with carbonic acid. They are valuable in proportion to the quantity of carbonate of lime they contain, and to the fineness of division of their parts.

In Scotland we often hear of soils that have been scorched with lime. Such soils grow green crops and grass well enough but not grain crops. The cases of this kind that have come under my notice have been chiefly thin soils recently reclaimed, and naturally deficient in lime. On examining both soil and subsoil, I found the quantity of lime present so small as at once to shew, at least, that excess of lime is not the cause of the continuance of the evil. It appears in

I mentioned bituminous limestones. There is very seldom any considerable portion of coaly matter in these stones; never as much as five parts in 100; but such limestones make very good lime. The carbonaceous matter can do no injury to the land, and may, under certain circumstances become a food of the plant, as is evident from what was stated in the last Lecture.*

The subject of the application of the magnesian limestone is one of great interest.

It had been long known to farmers in the neighbourhood of Doncaster, that lime made from a certain limestone applied to the land, often injured the crops considerably, as I mentioned in the Introductory Lecture. Mr Tennant, in making a series of experiments upon this peculiar calcareous substance, found that it contained magnesia; and on mixing some calcined magnesia with soil, in which he sowed different seeds, he found that they either died, or vegetated in a very imperfect manner, and the plants were never healthy. And with great justice and ingenuity he referred the bad effects of the peculiar limestone to the magnesian earth it contains.

In making some enquiries concerning this subject, I found that there were cases in which this magnesian limestone was used with good effect.

Amongst some specimens of limestones which Lord Somerville put into my hands, two marked as peculiarly good proved to be magnesian limestones. And lime made from the Breedon limestone is used in Leicestershire, where it is called hot lime; and I have been informed by farmers in the neighbourhood of the quarry, that they employ it advantageously in small quantities, seldom more than 25 or 30 bushels to the acre. And that they find it may be used with good effect in larger quantities upon rich land. A minute chemical consideration of this question will lead to its solution.

Magnesia has a much weaker attraction for carbonic acid than lime, and will remain in the state of caustic or calcined magnesia for many months, though exposed to the air. And as long as any caustic lime remains, the magnesia cannot be combined with carbonic acid, for lime instantly attracts carbonic acid from magnesia.

these cases to be the result of exhaustion from over cropping, immediately after the application of the lime. This explanation is borne out by the fact, that effects precisely similar are known to be produced on the same soils by the immoderate use of whale blubber, fish refuse, and slaughter-house offal.

* Many of the bituminous limestones owe the greater part of their calcareous matter to the shells of moluscous animals, and their bituminous matters to the bodies of the same animals. These limestones generally contain a variable proportion of clay, sand, and oxide of iron, which detract from their value as manures; but in many of the specimens I have examined, especially those from the lias, I have found as much phosphoric acid as to compensate for a considerable percentage of foreign matter, and render them fully as valuable as the purer primary limes.

Associated with the limestone beds of the lias, as well as in some other groups, there occur layers of shale abounding in shells and bituminous matter, and containing phosphates in very appreciable quantity. These shales when fresh dug are soft and friable, and readily crumble under the action of frost. In a few localities this kind of shale has been used as a top-dressing to light soils with remarkably good and lasting effect; and as it occurs in large quantity, and in many places, it deserves greater attention than some of the recent marls.

When a magnesian limestone is burnt, the magnesia is deprived of carbonic acid much sooner than the lime; and if there is not much vegetable or animal matter in the soil to supply carbonic acid by its decomposition, the magnesia will remain for a long while in the caustic state; and in this state acts as a poison to certain vegetables. And that more magnesian lime may be used upon rich soils, seems to be owing to the circumstance, that the decomposition of the manure in them supplies carbonic acid. And magnesia in its mild state, *i. e.* fully combined with carbonic acid, seems to be always an useful constituent of soils. I have thrown carbonate of magnesia (procured by boiling the solution of magnesia in super-carbonate of potassa) upon grass, and upon growing wheat and barley, so as to render the surface white; but the vegetation was not injured in the slightest degree. And one of the most fertile parts of Cornwal, the Lizard, is a district in which the soil contains mild magnesian earth.

The Lizard Downs bear a short and green grass, which feeds sheep, producing excellent mutton; and the cultivated parts are amongst the best corn lands in the county.

That the theory which I have ventured to give of the operation of magnesian lime is not unfounded, is shewn by an experiment which I made expressly for the purpose of determining the true nature of the operation of this substance. I took four portions of the same soil: with one I mixed $\frac{1}{20}$ of its weight of caustic magnesia, with another I mixed the same quantity of magnesia and a proportion of a fat decomposing peat equal to one-fourth of the weight of the soil. One portion of soil remained in its natural state: and another was mixed with peat without magnesia. The mixtures were made in December, 1806; and in April, 1807, barley was sown in all of them. It grew very well in the pure soil; but better in the soil containing the magnesia and peat; and nearly as well in the soil containing peat alone: but in the soil containing the magnesia alone, it rose very feeble, and looked yellow and sickly.

I repeated this experiment in the summer of 1810 with similar results; and I found that the magnesia in the soil mixed with peat became strongly effervescent, whilst the portion in the unmixed soil gave carbonic acid in much smaller quantities. In the one case the magnesia had assisted in the formation of a manure, and had become mild; in the other case it had acted as a poison.

It is obvious from what has been said, that lime from the magnesian limestone may be applied in large quantities to peats; and that where lands have been injured by the application of too large a quantity of magnesian lime, peat will be a proper and efficient remedy.

I mentioned that magnesian limestones effervesced little when plunged into an acid. A simple test of magnesia in a limestone is this circumstance, and its rendering diluted nitric acid, or aqua fortis milky.

From the analysis of Mr Tennant, it appears that the magnesian limestones contain from

20·3 to 22·5 magnesia.
29·5 to 31·7 lime.
47·2 carbonic acid.
0·8 clay and oxide of iron.

Magnesian limestones are usually coloured brown or pale yellow. They are found in Sommersetshire, Leicestershire, Derbyshire, Shropshire, Durham and Yorkshire. I have never met with any in other counties in

England; but they abound in many parts of Ireland, particularly near Belfast. *

The use of lime as a cement is not a proper subject for extensive discussion in a course of Lectures on the chemistry of agriculture; yet, as the theory of the operation of lime in this way is not fully stated in any elementary book that I have perused, I shall say a very few words on the application of this part of chemical knowledge.

There are two modes in which lime acts as a cement; in its combination with water, and in its combination with carbonic acid.

The hydrate of lime has been already mentioned. When quicklime is rapidly made into a paste with water, it soon loses its softness, and the water and the lime form together a solid coherent mass, which consists, as has been stated before, of 17 parts of water to 55 parts of lime. When hydrate of lime, whilst it is consolidating, is mixed with red oxide of iron, alumina, or silicà, the mixture becomes harder and more coherent than when lime alone is used; and it appears that this is owing to a certain degree of chemical attraction between hydrate of lime and these bodies; and they render it less liable to decompose by the action of the carbonic acid in the air, and less soluble in water.

The basis of all cements that are used for works which are to be covered with water must be formed from hydrate of lime; and the lime made from impure limestones answers this purpose very well. Puzzolana is composed principally of silica, alumina, and oxide of iron; and it is used mixed with lime to form cements intended to be employed under water. Mr Smeaton, in the construction of the Eddystone lighthouse, used a cement composed of equal parts by weight of slaked lime and puzzolana. Puzzolana is a decomposed lava. Tarras, which was formerly imported in considerable quantities from Holland, is a mere decomposed basalt: two parts of slaked lime and one part of tarras forms the principal part of the mortar used in the great dykes of Holland. Substances which will answer all the ends of puzzolana and tarras are abundant in the British islands. An excellent red tarras may be procured in any quantities from the Giants' Causeway in the north of Ireland; and decomposing basalt is abundant in many parts of Scotland, and in the northern districts of England in which coal is found.

Parker's cement, and cements of the same kind made at the alum works of Lord Dundas and Lord Mulgrave are mixtures of calcined ferruginous stones, with hydrate of lime.

The cements which act by combining with carbonic acid, or the common mortars, are made by mixing together slaked lime and sand. These mortars, at first solidify as hydrates, and are slowly converted into carbonate of lime by the action of the carbonic acid of the air. Mr Tennant found

* Almost all limestones, even those associated with primary rocks, contain small quantities of magnesia; and had it been more carefully sought for it would have more frequently appeared in tables of analyses of limestones. Magnesia, however, abounds most in the secondary limestones. Sometimes these are regular Dolomites consisting of single equivalents of carbonate of lime and carbonate of magnesia, but more frequently the carbonate of magnesia is present in considerably smaller proportion. The limestones associated with Serpentine and Dialage generally contain a good deal of magnesia. Of late years much less has been said regarding the injury done to land by magnesian lime, and the prevailing opinion now is, that when applied in moderate doses and with ordinary skill, it answers quite as well as the purer varieties.

that a mortar of this kind in three years and a quarter had regained 63 per cent. of the quantity of carbonic acid gas which constitutes the definite proportion in carbonate of lime. The rubbish of mortar from houses owes its power to benefit lands principally to the carbonate of lime it contains; and the sand in it; and its state of cohesion renders it particularly fitted to improve clayey soils.

The hardness of the mortar in very old buildings depends upon the perfect conversion of all its parts into carbonate of lime. The purest limestones are the best adapted for making this kind of mortar; the magnesian limestones make excellent water cements; but act with too little energy upon carbonic acid gas to make good common mortar.

The Romans, according to Pliny, made their best mortar a year before it was used; so that it was partially combined with carbonic acid gas before it was employed.

In burning lime there are some particular precautions required for the different kinds of limestones. In general, one bushel of coal is sufficient to make four or five bushels of lime. The magnesian limestone requires less fuel than the common limestone. In all cases in which a limestone containing much aluminous or siliceous earth is burnt, great care should be taken to prevent the fire from becoming too intense; for such lime easily vitrifies, in consequence of the affinity of lime for silica and alumina. And as in some places there are no other limestones than such as contain other earths, it is important to attend to this circumstance. A moderately good lime may be made at a low red heat: but it will melt into a glass at a white heat. In limekilns for burning such lime, there should be always a damper.

In general, when limestones are not magnesia their purity will be indicated by their loss of weight in burning; the more they lose the larger is the quantity of calcareous matter they contain. The magnesian limestones contain more carbonic acid than the common limestones; and I have found all of them lose more than half their weight by calcination. *

Besides being used in the forms of lime and carbonate of lime, calcareous matter is applied for the purposes of agriculture in other combinations. One of these bodies is *gypsum* or sulphate of lime. This substance consists of sulphuric acid (the same body that exists combined with water in oil of vitriol) and lime; and when dry it is composed of 55 parts of lime and 75 parts of sulphuric acid. Common gypsum or selenite, such

* One of the forms of draining tile that has lately attracted a good deal of attention is that of Lord James Hay. This tile consists of a sort of *concrete* composed of slaked lime, sand, and grit. From the cheap rate at which, in many localities, it can be prepared, it deserves greater attention than it has hitherto met with. From the trials that have come under my own observation I am led to conclude that it is cheapest when made from pure lime, on account of the larger proportion of sand and grit that such a lime is capable of taking; but then, it is more brittle, and, under certain circumstances not yet investigated, liable to soften. In some cases where pure lime has been used, the tile has been found to stand better when the mixture was made and allowed to sour for some months before the tiles were formed. When made from hydraulic lime, however, which takes a much smaller proportion of sand and grit, the tile stands well, and can be used immediately, but is, of course, more expensive. In districts where only pure lime occurs, it deserves a trial whether an admixture of burnt clay would not be advantageous.

as that found at Shotover hill near Oxford, contains besides sulphuric acid and lime, a considerable quantity of water; and its composition may be thus expressed:—

Sulphuric acid, one proportion, .	75
Lime, one proportion, . . .	55
Water, two proportions, . . .	34 *

The nature of gypsum is easily demonstrated: if oil of vitriol be added to quicklime there is a violent heat produced; when the mixture is ignited, water is given off, and gypsum alone is the result, if the acid has been used in sufficient quantity; and gypsum mixed with quicklime, if the quantity has been deficient. Gypsum free from water is sometimes found in nature, and it is called anhydrous selenite. It is distinguished from common gypsum by giving off no water when heated.

When gypsum free from water, or deprived of water by heat, is made into a paste with water, it rapidly sets by combining with that fluid. Plaster of Paris is powdered dry gypsum, and its property as a cement, and in its use in making casts depends upon its solidifying a certain quantity of water, and making with it a coherent mass. Gypsum is soluble in about 500 times its weight of cold water, and is more soluble in hot water; so that when water has been boiled in contact with gypsum, crystals of this substance are deposited as the water cools. Gypsum is easily distinguished when dissolved by its properties of affording precipitates to solutions of oxalates and of barytic salts.

Great difference of opinion has prevailed amongst agriculturists with respect to the uses of gypsum. It has been advantageously used in Kent, and various testimonies in favour of its efficacy have been laid before the Board of Agrigulture by Mr Smith. In America it is employed with signal success; but in most counties of England it has failed, though tried in various ways, and upon different crops.

Very discordant notions have been formed as to the mode of operation of gypsum. It has been supposed by some persons to act by its power of attracting moisture from the air; but this agency must be comparatively insignificant. When *combined* with water it retains that fluid too powerfully to yield it to the roots of the plant, and its adhesive attraction for moisture is inconsiderable; the small quantity in which it is used likewise is a circumstance hostile to this idea.

It has been said that gypsum assists the putrefaction of animal substances, and the decomposition of manure. I have tried some experiments on this subject which are contradictory to the notion. I mixed some minced veal with about $\frac{1}{100}$ part of its weight of gypsum, and exposed some veal without gypsum under the same circumstances; there was no difference in the time in which they began to putrefy; and the process seemed to me most rapid in the case in which there was no gypsum present. I made other similar mixtures, employing in some cases larger, and in some cases smaller quantities of gypsum; and I used pigeons' dung in one instance instead of flesh, and with precisely similar results. It certainly in no case increased the rapidity of putrefaction. †

* Or more correctly of sulphuric acid 40·1, lime 28·5, and water 18.

† Liebig maintains that apart from its being directly nutritive to plants, one of the principal functions of gypsum is to fix the ammonia that falls as carbonate in rain and snow, as well as what arises from the decomposition of organic matter in the soil; mutual decomposition of the two salts takes place, and sul-

Though it is not generally known, yet a series of experiments has been carried on for a great length of time in this country upon the operation of gypsum as a manure. The Berkshire and the Wiltshire peat-ashes contain a considerable portion of this substance. In the Newbury peat-ashes I have found from one-fourth to one-third of gypsum; and a larger quantity in some peat-ashes from the neighbourhood of Stockbridge: the other constituents of these ashes are calcareous, aluminous, and siliceous earth, with variable quantities of sulphate of potassa, a little common salt and sometimes oxide of iron. The red ashes contain most of this last substance.

These peat-ashes are used as a top dressing for cultivated grasses, particularly sainfoin and clover. In examining the ashes of sainfoin, clover, and rye-grass, I found that they afforded considerable quantities of gypsum; and this substance, probably, is intimately combined as a necessary part of their woody fibre. If this be allowed, it is easy to explain the reason why it operates in such small quantities; for the whole of a clover crop, or sainfoin crop, on an acre, according to my estimation, would afford by incineration only three or four bushels of gypsum. In examining the soil in a field near Newbury, which was taken from below a foot-path near the gate, where gypsum could not have been artificially furnished, I could not detect any of this substance in it: and at the very time I collected the soil, the peat-ashes were applied to the clover in the field. The reason why gypsum is not generally efficacious, is probably because most cultivated soils contain it in sufficient quantities for the use of the grasses. In the common course of cultivation, gypsum is furnished in the manure; for it is contained in stable dung, and in the dung of all cattle fed on grass; and it is not taken up in corn crops, or crops of peas and beans, and in very small quantities in turnip crops; but where lands are exclusively devoted to pasturage and hay, it will be continually consumed. I have examined four different soils cultivated by a series of common courses of

phate of ammonia and carbonate of lime are produced. For the same purpose he recommends the strewing of powdered gypsum in stables and cow-houses, and on fermenting dunghills. This suggestion has been very generally adopted, and powdered gypsum is now regularly sold by dealers in manures. For the urine tank gypsum is less fitted, it falls to the bottom, and unless the contents are constantly stirred, some ammonia is lost. Sulphuric acid is therefore always to be preferred for using in the tank. For strewing on stable floors, and particularly on dunghills, gypsum answers better; yet it is too slow in its action to free the air of stables entirely of ammoniacal vapours, as any one may perceive by carrying a moistened litmus paper into a stable, the door of which has remained for a short time shut. It is, therefore, better to use in stables charcoal slightly moistened with sulphuric acid; only this mixture cannot be strewed on the floor on account of its injuring the horses feet. It is easy, however, to place it in a thin layer, on a board or slab, in some situation where it can do no harm. The mixture when it ceases to absorb ammoniacal vapours may be mixed with guano, or used by itself as a dressing for almost any crop.

I have tried gypsum on a great variety of soils, in general with but little success. In a few instances, however, it proved highly beneficial to clover. In these cases I observed that the advantage could not be detected by the eye, or even by the balance, when the produce was weighed green, but it was very apparent on weighing the dried hay. Gypsum is said to be more uniformly successful as a manure for potatoes than any other of the ordinary field-crops, but of this I cannot speak from personal observation. The low price of gypsum renders it a very important application in localities where it succeeds.

crops, for gypsum. One was a light sand from Norfolk; another a clay bearing good wheat from Middlesex; the third a sand from Sussex; the fourth a clay from Essex. I found gypsum in all of them; and in the Middlesex soil it amounted nearly to one per cent. Lord Dundas informs me, that having tried gypsum without any benefit on two of his estates in Yorkshire, he was induced to have the soil examined for gypsum according to the process described in the Fourth Lecture, and this substance was found in both the soils.

Should these statements be confirmed by future enquiries, a practical inference of some value may be derived from them. It is possible that lands which have ceased to bear good crops of clover, or artificial grasses, may be restored by being manured with gypsum. I have mentioned that this substance is found in Oxfordshire; it is likewise abundant in many other parts of England; in Gloucestershire, Somersetshire, Derbyshire, Yorkshire, &c., and requires only pulverization for its preparation.

Some very interesting documents upon the use of sulphate of iron or green vitriol, which is a salt produced from peat in Bedfordshire, have been laid before the Board by Dr. Pearson; and I have witnessed the fertilizing effects of a ferruginous water used for irrigating a grass meadow made by the Duke of Manchester, at Priestley Bog near Woburn, an account of the produce of which has been published by the Board of Agriculture. I have no doubt that the peat salt and the vitriolic water acted chiefly by producing gypsum.

The soils on which both are efficacious are calcareous; and sulphate of iron is decomposed by the carbonate of lime in such soils. The sulphate of iron consists of sulphuric acid and oxide of iron, and is an acid and a very soluble salt; when a solution of it is mixed with carbonate of lime, the sulphuric acid quits the oxide of iron to unite to the lime, and the compounds produced are insipid and comparatively insoluble.

I collected some of the deposition from the ferruginous water on the soil in Priestley meadow. I found it consisted of gypsum, carbonate of iron, and insoluble sulphate of iron. The principal grasses in Priestley meadow are, meadow fox-tail, cock's foot, meadow fescue, fiorin, and sweetscented vernal grass. I have examined the ashes of three of these grasses, meadow fox-tail, cock's-foot and fiorin. They contained a considerable proportion of gypsum.

Vitriolic impregnations in soils where there is no calcareous matter, as in a soil from Lincolnshire, to which I referred in the Fourth Lecture, are injurious; but it is probably in consequence of their supplying an excess of ferruginous matter to the sap. Oxide of iron in small quantities forms a useful part of soils; and, as is evident from the details in the Third Lecture, it is found in the ashes of plants; and probably, is hurtful only in its acid combinations.

I have just mentioned certain peats, the ashes of which afford gypsum; but it must not be inferred from this that all peats agree with them. I have examined various peat-ashes from Scotland, Ireland, Wales, and the northern and western parts of England, which contained no quantity that could be useful; and these ashes abounded in siliceous, aluminous earths, and oxide of iron.

Lord Charleville found in some peat-ashes from Ireland sulphate of potassa, *i. e.* the sulphuric acid combined with potassa.

Vitriolic matter is usually formed in peats; and if the soil or substratum is calcareous, the ultimate result is the production of gypsum. In general,

when a recent peat-ash emits a strong smell resembling that of rotten eggs when acted upon by vinegar, it will furnish gypsum.

Phosphate of Lime is a combination of phosphoric acid and lime, one proportion of each. It is a compound insoluble in pure water, but soluble in water containing any acid matter. It forms the greatest part of calcined bones. It exists in most excrementitious substances, and is found both in the straw and grain of wheat, barley, oats, and rye, and likewise in beans, peas, and tares. It exists in some places in these islands native; but only in very small quantities. Phosphate of lime is generally conveyed to the land in the composition of other manure; and it is probably necessary to corn crops and other white crops.

Bone ashes ground to powder will probably be found useful on arable lands containing much vegetable matter, and may perhaps enable soft peats to produce wheat; but the powdered bone in an uncalcined state is much to be preferred in all cases when it can be procured. *

The *saline compounds of magnesia* will require very little discussion as to their uses as manures. The most important relations of this subject to agriculture have been considered in the former part of this Lecture, when the application of the magnesian limestone was examined. In combination with sulphuric acid, magnesia forms a soluble salt. This substance it is stated by some enquirers, has been found of use as a manure; but it is not found in nature in sufficient abundance, nor is it capable of being made artificially sufficiently cheap to be of useful application in the common course of husbandry. †

Wood ashes consists principally of the vegetable alkali united to carbonic acid; and as this alkali is found in almost all plants, it is not difficult to conceive that it may form an essential part of their organs. The general tendency of the alkalies is to give solubility to vegetable matters; and in this way they may render carbonaceous and other substances capable of being taken up by the tubes in the radicle fibres of plants. The vegetable alkali likewise has a strong attraction for water, and even in small quantities may tend to give a due degree of moisture to the soil, or to other manures; though this operation from the small quantities used, or existing in the soil, can be only of a secondary kind. ‡

* See note p. 227.

† From various causes sulphate of magnesia has fallen much in price, and may now be had in crystals but slightly coloured at a rate low enough to enable farmers to employ it as a manure. I have seen it used with great advantage as a manure for potatoes, either mixed with guano, or bone-dust prepared with sulphuric acid. In the former case it was used at the rate of one cwt. of the salt to four cwt. of guano per acre, and in the latter one cwt. of the salt to twelve bushels of the prepared bone-dust. In light soils, deficient in organic matter, it has been found preferable to use half the above quantities in addition to ten tons of well made farm-yard manure. The potatoes grown after these mixtures have proved remarkably sound and fit for seed. Sulphate of magnesia has been used as a dressing for wheat and other grain-crops, and generally with advantage.

‡ The fact that alkaline carbonates occur in the ashes of all plants, is enough to shew that alkalies are indispensable, and that if the soil cannot afford them in sufficient abundance, they must be added in the manure. Other functions, however than those specified in the text have been justly assigned to them. Liebig has shewn that the formation of organic acids in a plant is regulated by the supply of base it can obtain; and again, silica which occurs so largely, particularly in the straw and husk of grain-crops, cannot be conceived to be acquired

The *mineral alkali or soda*, is found in the ashes of sea-weed, and may be procured by certain chemical agencies from *common salt*. Common salt consists of the metal named sodium, combined with chlorine; and pure soda consists of the same metal united to oxygen. When water is present which can afford oxygen to the sodium, soda may be obtained in several modes from salt.

The same reasoning will apply to the operation of the pure mineral alkali, or the carbonated alkali, as to that of the vegetable alkali; and when common salt acts as a manure, it is probably by entering into the composition of the plant in the same manner as gypsum, phosphate of lime, and the alkalies. Sir John Pringle has stated, that salt in small quantities assists the decomposition of animal and vegetable matter. This circumstance may render it useful in certain soils. Common salt likewise is offensive to insects. *—That in small quantities it is sometimes a useful manure, I believe is fully proved; and it is probable that its efficacy depends upon many combined causes.

Some persons have argued against the employment of salt; because when used in large quantities, it either does no good, or renders the ground sterile; but this is a very unfair mode of reasoning. That salt in large quantities rendered land barren, was known long before any records of agricultural science existed. We read in the Scriptures, that Abimelech took the city of Shechem, "and beat down the city, and sowed it with salt; that the soil might be for ever unfruitful." Virgil reprobates a salt soil; and Pliny, though he recommends giving salt to cattle, yet affirms, that when strewed over land it renders it barren. But these are not arguments against a proper application of it. Refuse salt in Cornwall, which, however, likewise contains some of the oil and exuviæ of fish, has long been known as an admirable manure. And the Cheshire farmers contend for the benefit of the peculiar produce of their country.

It is not unlikely that the same causes influence the effects of salt, as those which act in modifying the operation of gypsum. Most lands in this Island, particularly those near the sea, probably contain a sufficient quantity of salt for all the purposes of vegetation; and in such cases the supply of it to the soil will not only be useless, but may be injurious. In great storms the spray of the sea has been carried more than 50 miles from the shore; so that from this source salt must be often supplied to the soil. I have found salt in all the sandstone rocks that I have examined, and it must exist in the soil derived from these rocks. It is a constituent likewise of almost every kind of animal and vegetable manure. †

otherwise than through the agency of alkalies. The alkaline carbonates are too valuable in the arts to be sold at such a price as to be a profitable manure; but evidence of their efficiency is not awanting; thus, the immediate effect of wood ashes is known to be nearly proportional to the amount of carbonate of potash they contain; and *kelp*, which contains carbonate of soda, has, since it was less used in the arts, been beneficially employed as a manure.

* Salt is more frequently employed for this purpose in the garden than in the field. It is very often applied to onion beds and lines, to destroy the maggot that attacks the roots of the plants, especially when young. The salt is sown on the ground in dry weather, and water sprinkled over it to dissolve and carry down the salt. Nitrate of soda has of late been used for the same purpose, and is preferred to common salt, for while it is equally certain in destroying the maggot, it is more beneficial to the sound plants.

† More extended experience has fully confirmed these views regarding the use of salt. It is now well known that it is only in inland situations that salt can

Besides these compounds of the alkaline earths and alkalies, many others have been recommended for the purposes of increasing vegetation; such are *nitre*, or the nitrous acid combined with potassa. Sir Kenelm Digby states, that he made barley grow very luxuriantly by watering it with a very weak solution of nitre; but he is too speculative a writer to awaken confidence in his results. This substance consists of one proportion of azote, six of oxygen, and one of potassium; and it is not unlikely that it may furnish azote to form albumen or gluten in those plants that contain them; but the nitrous salts are too valuable for other purposes to be used as manures. *

Dr. Home states, that *sulphate of potassa* which, as I just now mentioned, is found in the ashes of some peats, is a useful manure. But Mr Naismith † questions his results; and quotes experiments hostile to his opinion, and, as he conceives, unfavourable to the efficacy of any species of saline manure. ‡

be profitably employed. In some cases it is simply sown at the rate of three or four cwt. per acre, as a top-dressing to grass and grain-crops: but it is generally found more efficient when used in compost with earth or peat and lime. The mixture should be made at least a year before it is to be applied, frequent turning is advantageous, and it should be protected from the rain, yet not allowed to get too dry.

* Since the discovery of nitrate of soda in South America, the price has fallen so low as to admit of its employment as a manure; and many statements have been published shewing that it has been used with great advantage. From my own experience I am led to conclude that it acts very differently on different soils, and in different seasons. The most profitable results I have seen from its use were, when it was applied to grain crops, especially barley, on soils of good quality, and containing a fair proportion of organic matter. In a day or two after its application the plants assume a deeper green tint, and more healthy appearance; and a considerable increase of grain, with a still greater increase of straw, is reaped. The grain, however, I have generally remarked to be somewhat lighter per bushel, and rather inferior in colour. When applied to grass and clover, to be cut as hay, it is found to act principally on the rye-grass, and to produce little or no effect on the clover. I have seen it beneficially applied to turnips, on light soils, but only when used in compost, or in addition to farm-yard manure.

On other soils, again, I have known little or no effect produced by it beyond deepening the colour of the plants for a time. In cases where it succeeds, I have always found the crop a few days later than on undressed portions of the same fields. To grain crops it is applied at the rate of 1 to 1½ cwt. per acre, and on the braird rather than along with the seed. Like all the soluble saline manures, it never lasts beyond a single season.

Nitrate of soda as imported contains a variable percentage of common salt, I have often examined samples that contained less than 1 per cent; generally it contains 2 or 3, but I have found it with as much as 36 per cent. Different bags of the same cargo vary considerably. When purchased for chemical purposes, it is almost always upon analysis, but as less attention is given to the purity of manures, there is reason to believe that not only is it the worst samples that are offered in the manure market, but that it is occasionally adulterated with common salt.

As a manure, nitrate of potash is equally useful if not more so, but its higher price at present prevents it from being much used.

Nothing very satisfactory has hitherto been ascertained regarding the manner in which nitrates act within the plant.

† Elements of Agriculture, p. 78.

‡ The sulphates of potash, soda, and magnesia, have all proved useful manures. From the abundance and comparative cheapness of soda salts, they are more

Much of the discordance of the evidence relating to the efficacy of saline substances depends upon the circumstance of their having been used in different proportions, and in general in quantities much too large.

I made a number of experiments in May and June, 1807, on the effects of different saline substances on barley and on grass growing in the same garden, the soil of which was a light sand, of which 100 parts were composed of 60 parts of siliceous sand, and 24 parts finely divided matter, consisting of 7 parts carbonate of lime, 12 parts alumina and silica, less than one part saline matter, principally common salt, with a trace of gypsum and sulphate of magnesia: the remaining 16 parts were vegetable matter.

The solutions of the saline substances were used twice a week, in the quantity of two ounces, on spots of grass and corn, sufficiently remote from each other to prevent any interference of results. The substances tried were *super-carbonate, sulphate, acetate, nitrate*, and *muriate of potassa*, and *sulphate of soda; sulphate, nitrate, muriate*, and *carbonate of ammonia*. I found that in all cases when the quantity of the salt equalled $\frac{1}{30}$ part of the weight of the water, the effects were injurious; but least so in the instances of the carbonate, sulphate, and muriate of ammonia. When the quantities of the salts were $\frac{1}{300}$ part of the solution the effects were different. The plants watered with the solutions of the sulphates grew just in the same manner as similar plants watered with rain water. Those acted on by the solution of nitre, acetate, and super-carbonate of potassa, and muriate of ammonia grew rather better. Those treated with the solution of carbonate of ammonia grew most luxuriantly of all. This

used in chemical works than potash ones, and consequently, as residuary products can be offered at much lower prices.

Sulphate of soda in the crystalline form has been a good deal used, but the dry sulphate being a residuary product of several chemical manufactures, it is best to employ it in that state. The market price of the dry and crystallised salts is pretty much the same, but as the latter contains nearly 56 per cent. of water, no one can hesitate as to which to employ; and even in the event of the prices becoming more nearly proportional to their actual values, the saving in carriage and application is considerable. But there is another advantage in using the dry salt, it often contains a good deal of free acid, which renders it particularly fit for being mixed with guano to fix its free ammonia, or even to fix the ammonia of the urine tank. The sulphate of soda, like all saline manures, is best used along with other manures.

I have seen sulphate of soda most frequently applied to grain-crops; while it increases the yield of straw, the quality and colour of the grain are not deteriorated. Among many experimental trials made in the vicinity of Aberdeen in 1843, one of the most profitable returns followed the use of a mixture of sulphate and nitrate of soda, on a crop of oats after lea. The salts were sown on the braird in its third leaf, 1 cwt of the nitrate, and 1½ cwt. of the sulphate being used per acre. Comparing the plot that had no dressing with this, the best plot of the series, the result was as follows:—

	Marketable Grain. Bs.	Weight of Grain per Bs. Lbs.	Straw. Cwt.
No application, ...	24·	41¼	13·
Nitrate and sulphate of soda, . .	44·	42½	58·

There were other plots on the same field dressed with the two salts separately, but the mixture answered better than either.

Sulphate of soda has been applied to potatoes with great advantage, especially when mixed with guano. All the sulphates seem particularly favourable to the growth of oats.

last result is what might be expected, for carbonate of ammonia consists of carbon, hydrogen, azote, and oxygen. There was, however, another result which I had not anticipated; the plants watered with solution of nitrate of ammonia did not grow better than those watered with rain water. The solution reddened litmus paper; and probably the free acid exerted a prejudicial effect, and interfered with the result. *

* Ammoniacal salts have been shewn in all recent experiments to be the most active of saline manures. I have tried the chloride, (sal-ammoniac,) the sulphate, and the nitrate of ammonia. The chloride although very valuable, I have found less efficient than the sulphate, and the sulphate less than the nitrate.

A practical consideration of some consequence is, that of ammoniacal salts the sulphate is the only one that has hitherto found its way into the manure market sufficiently pure, and at the same time cheap enough to admit of its being applied to the land. This arises chiefly from its being prepared at a cheap rate from gas-water, and from sulphuric acid being used in some places in the purification of coal gas. There is no reason why sal-ammoniac, if it answered as well, might not be got proportionally cheap, but the nitrate, which I have no hesitation in pronouncing the best of all, cannot be used on account of its expense.

The impurities found in the sulphate, from gas-works, are principally some coal tar and thickened naphtha, which require considerable care in the manufacture to separate them. They seldom amount to much, neither indeed can they, for they give the salt so dark a colour, and disagreeable smell, that it passes for being more impure than it really is. Iron is another, and a most noxious impurity in the gas sulphate. It never occurs but when the makers are new to the business and ignorant of chemistry. It arises from neglecting to keep the solution slightly alkaline during the time it is in the iron evaporating pan. Iron may be easily kept out, but when once it gets in, it is removed with great difficulty. When there is much iron present, the salt is dark, of a green colour when new, and becomes red on exposure. Sulphate of ammonia, containing iron, ought not to be purchased at any price, but simply rejected.

The impurities above specified, occur in the salt through carelessness or want of skill on the part of the manufacturer, but I have met with some specimens of sulphate made from gas-water, of fine colour, and in unusually large crystals, that contained a large quantity of sulphate of soda which had obviously been added as a make-weight. Salt of this kind assumes a floury appearance when dried, or exposed for a few days in a dry atmosphere. The impurity is better detected by cautiously igniting a little of the sulphate on a slip of platinum foil, when the sulphate of ammonia will rise in vapour, leaving the fixed salt behind.

In some of the large towns, sulphate of ammonia is prepared from urine. The urine is collected, acidulated with sulphuric acid, allowed to putrefy, and then evaporated. A large proportion of the saline mass thus obtained, consists of sulphate of ammonia, but there are also present all the fixed salts of the urine. The mixture has a dark colour, and peculiar urinous odour, especially when heated. Weight for weight, it is more valuable than the pure sulphate of ammonia, but being, when honestly prepared, but a dark coloured mixture of salts, good samples have difficulty in competing in the market with better looking, but largely adulterated ones, prepared by less scrupulous parties.

Sulphate of ammonia is not so capricious in regard to soils as nitrate of soda; and with quite as great a tendency to increase the bulk of straw, it gives weightier and better coloured grain. It pays best on a grain-crop after lea, and on land containing plenty of organic matter. To winter wheat it is best applied in spring on the approach of fine weather. Like many other saline manures it is not so applicable to a grain crop sown down with grass and clover, because from its tendency to give a great increase of straw, the *sole* of grass is by so much the worse, and the grass can derive no benefit from it, for its effect lasts only a season. For a grain crop sown down with grass and clover, I have found nothing equal to the prepared bone-dust formerly mentioned.

On old lawns that have lost tint, and got moss-grown, I have seen a complete

Soot doubtless owes a part of its efficacy to the ammoniacal salts it contains. The liquor produced by the distillation of coal, contains carbonate and acetate of ammonia, and is said to be a very good manure. *

In 1808, I found the growth of wheat in a field at Roehampton, assisted by a very weak solution of acetate of ammonia.

Soapers' waste has been recommended as a manure, and it has been supposed that its efficacy depended upon the different saline matters it contains; but their quantity is very minute indeed, and its principal ingredients are mild lime and quicklime. In the soapers' waste from the best manufactories, there is scarcely a trace of alkali. Lime moistened

extirpation of moss, accompanied with a restoration of the finest verdure, after an application of 1½ cwt. of sulphate of ammonia, and five or six bushels of the dry preparation of bone-dust with sulphuric acid.

* Gas-water has frequently been used as a manure, but never without loss, on account of the volatility of the ammonia. Crude gas-water cannot be applied to growing crops without scorching them; this it is true, may be obviated by sufficient dilution, but then the expense of applying it is increased, and no dilution can deprive the sulphuret of ammonium, the tar and naphtha which are always present, of their poisonous properties. Out of many trials of crude gas-water, the only tolerably successful instance of its application I have found, was, when applied to permanent pasture early in spring. Any verdure that happened to exist was scorched, but when spring growth set in, it was vigorously, and the grass was much improved. There can be no doubt, however, that it would have done more good had it been neutralised with sulphuric acid and applied at a later period.

At small gas-works, where the quantity of gas-water produced in a season is inconsiderable, it is not worth while erecting apparatus for crystallising the sulphate. The best way in such cases is to have a double set of tar-wells, so constructed as to act as tar and naphtha separatories. When one set is filled, the liquid products of the hydraulic main are directed into the other, so that they may accumulate in it while separation goes on in the first. After standing a few weeks, the naphtha holding some tar in solution may be run off from the upper chamber, after which, the water now tolerably clear, but of a brown tint, may be run off into a vat or tank, leaving the tar in the bottom. The ammoniacal water is next neutralised with sulphuric acid and allowed to stand for a few days, some finely powdered resin is sifted on the top of the liquid; in a few hours the resin can be removed in a soft visced mass, taking along with it a portion of the dissolved naphtha, which the heat evolved on the addition of the acid served to separate and bring to the top. The neutralised solution may be run off and applied to growing crops by the water cart.

The strength of gas-water varies with the quality and dryness of the coal used, the heat at which the retorts are ignited, and the nature and extent of the condensing apparatus. When the best cannel coal is employed, and the heat properly regulated, I have found that a gallon of water takes, on an average, 5100 grains of sulphuric acid of density 1·71 to neutralise it. The quantity of gas-water depends of course on the amount of coals distilled. I have found, even in gas-works where only the ammonia that finds its way into the tar-well was saved, that 100 tons of coals afford a quantity of gas-water which, were it neutralised and evaporated without loss, would afford rather more than a ton of crystallised sulphate of ammonia.

At large gas-works it will be found that the neutralised water cannot be all sold in that state on account of the great expense of carriage and application when compared with the salt, hence it must be purified and evaporated. It would be out of place here to enter into details regarding the best methods of this process, as in large towns competent chemical advice can always be obtained. It may be mentioned, however, that with moderate skill, it is easy to obtain the salt beautifully crystallised, and without a trace of colour.

with sea water affords more of this substance, and is said to have been used in some cases with more benefit than common lime.

It is unnecessary to discuss to any greater extent the effects of saline substances on vegetation; except the ammoniacal compounds, or the compounds containing nitric, acetic, and carbonic acid; none of them can afford by their decomposition any of the common principles of vegetation, carbon, hydrogen, and oxygen.

The alkaline sulphates, and the earthy muriates, are so seldom found in plants, or are found in such minute quantities, that it can never be an object to apply them to the soil. It was stated in the beginning of this Lecture, that the earthy and alkaline substances seem never to be formed in vegetation; and there is every reason likewise to believe, that they are never decomposed; for after being absorbed they are found in their ashes.

The metallic bases of them cannot exist in contact with aqueous fluids; and these metallic bases, like other metals, have not as yet been resolved into any other forms of matter by artificial processes; they combine readily with other elements; but they remain undestructible, and can be traced undiminished in quantity, through their diversified combinations.

LECTURE VIII.

ON THE IMPROVEMENT OF LANDS BY BURNING; CHEMICAL PRINCIPLES OF THIS OPERATION. ON IRRIGATION AND ITS EFFECTS. ON FALLOWING; ITS DISADVANTAGES AND USES. ON THE CONVERTIBLE HUSBANDRY FOUNDED ON REGULAR ROTATIONS OF DIFFERENT CROPS. ON PASTURE; VIEWS CONNECTED WITH ITS APPLICATION. ON VARIOUS AGRICULTURAL OBJECTS CONNECTED WITH CHEMISTRY. CONCLUSION.

THE improvement of sterile lands by burning was known to the Romans. It is mentioned by Virgil in the first book of the Georgics: "Sæpe etiam steriles incendere profuit agros." It is a practice still much in use in many parts of these Islands: the theory of its operation has occasioned much discussion, both amongst scientific men and farmers. It rests entirely upon chemical doctrines; and I trust I shall be able to offer you satisfactory elucidations on the subject.

The basis of all common soils, as I stated in the Fourth Lecture, are mixtures of the primitive earths and oxide of iron; and these earths have a certain degree of attraction for each other. To regard this attraction in its proper point of view, it is only necessary to consider the composition of any common siliceous stone. Feldspar, for instance, contains siliceous, aluminous, calcareous earths, fixed alkali, and oxide of iron, which exist in one compound, in consequence of their chemical attractions for each other. Let this stone be ground into impalpable powder, it then becomes a substance like clay: if the powder be heated very strongly it fuses, and on cooling forms a coherent mass similar to the original stone; the parts separated by mechanical division adhere again in consequence of chemical attraction. If the powder is heated less strongly the particles only superficially combine with each other, and form a gritty mass, which, when broken into pieces, has the characters of sand.

If the power of the powdered feldspar to absorb water from the atmosphere before, and after the application of the heat, be compared, it is found much less in the last case.

The same effect takes place when the powder of other siliceous or aluminous stones is made the subject of experiment.

I found that two equal portions of basalt ground into impalpable powder, of which one had been strongly ignited, and the other exposed only to a

temperature equal to that of boiling water, gained very different weights in the same time when exposed to air. In four hours the one had gained only two grains, whilst the other had gained seven grains.

When clay or tenacious soils are burnt, the effect is of the same kind; they are brought nearer to a state analogous to that of sands.

In the manufacture of bricks the general principle is well illustrated; if a piece of dry brick earth be applied to the tongue it will adhere to it very strongly, in consequence of its power to absorb water; but after it has been burnt there will be scarcely a sensible adhesion.

The process of burning renders the soil less compact, less tenacious and retentive of moisture; and when properly applied, may convert a matter that was stiff, damp, and in consequence cold, into one powdery, dry, and warm; and much more proper as a bed for vegetable life.

The great objection made by speculative chemists to paring and burning, is, that it destroys vegetable and animal matter, or the manure in the soil; but in cases in which the texture of its earthy ingredients is permanently improved, there is more than a compensation for this temporary disadvantage. And in some soils where there is an excess of inert vegetable matter, the destruction of it must be beneficial; and the carbonaceous matter remaining in the ashes may be more useful to the crop than the vegetable fibre, from which it was produced.

I have examined by a chemical analysis three specimens of ashes from different lands that had undergone paring and burning. The first was a quantity sent to the Board by Mr Boys of Bellhanger, in Kent, whose treatise on paring and burning has been published. They were from a chalk soil, and 200 grains contained

80 Carbonate of lime.
11 Gypsum.
9 Charcoal.
15 Oxide of iron.
3 Saline matter.
Sulphate of Potash.
Muriate of magnesia, with a minute quantity of vegetable alkali.

The remainder alumina and silica.

Mr Boys estimates that 2660 bushels are the common produce of an acre of ground, which, according to his calculation, would give 172900 lbs. containing

Carbonate of lime, ...	69160 lbs.
Gypsum, ...	9509·5
Oxide of iron, ...	12967·5
Saline matter, ...	2593·5
Charcoal, ...	7780·5

In this instance there was undoubtedly a very considerable quantity of matter capable of being active as manure produced in the operation of burning. The charcoal was very finely divided; and exposed on a large surface on the field, must have been gradually converted into carbonic acid.*

* Finely divided charcoal may be very useful in loosening and giving porosity to stiff clay, as well as in absorbing gases and vapours, which it afterwards renders up to the roots of plants; but, as has been already noticed, at common temperatures it is incapable of combining with oxygen.

And gypsum and oxide of iron, as I mentioned in the last Lecture, seem to produce the very best effects when applied to lands containing an excess of carbonate of lime.

The second specimen was from a soil near Coleorton, in Leicestershire, containing only four per cent. of carbonate of lime, and consisting of three-fourths light siliceous sand, and about one-fourth clay. This had been turf before burning, and 100 parts of the ashes gave

6 parts charcoal.
3 Muriate of soda and sulphate of potash, with a trace of vegetable alkali.
9 Oxide of iron.

And the remainder the earths.

In this instance, as in the other, finely divided charcoal was found; the solubility of which would be increased by the presence of the alkali.

The third instance was, that of a stiff clay, from Mount's Bay Cornwall. This land had been brought into cultivation from a heath by burning about ten years before; but having been neglected, furze was springing up in different parts of it, which gave rise to the second paring and burning. 100 parts of the ashes contained

8 parts of charcoal.
2 of saline matter, principally common salt, with a little vegetable alkali.
7 Oxide of iron.
2 Carbonate of lime.

Remainder alumina and silica.

Here the quantity of charcoal was greater than in the other instances. The salt, I suspect, was owing to the vicinity of the sea, it being but two miles off. In this land there was certainly an excess of dead vegetable fibre, as well as unprofitable living vegetable matter; and I have since heard, that a great improvement took place.

Many obscure causes have been referred to for the purpose of explaining the effects of paring and burning; but I believe they may be referred entirely to the diminution of the coherence and tenacity of clays, and to the destruction of inert, and useless vegetable matter, and its conversion into a manure.

Dr. Darwin, in his Phytologia, has supposed, that clay during torrefaction, may absorb some nutritive principles from the atmosphere that afterwards may be supplied to plants; but the earths are pure metallic oxides, saturated with oxygen; and the tendency of burning is to expel any other volatile principles that they may contain in combination. If the oxide of iron in soils is not saturated with oxygen, torrefaction tends to produce its further union with this principle; and hence in burning, the colour of clays changes to red. The oxide of iron containing its full proportion of oxygen has less attraction for acids than the other oxide, and is consequently less likely to be dissolved by any fluid acids in the soil; and it appears in this state to act in the same manner as the earths. A very ingenious author, whom I quoted at the end of the last Lecture, supposes that the oxide of iron when combined with carbonic acid is poisonous to plants; and that one use of torrefaction is to expel the carbonic acid from it; but the carbonate of iron is not soluble in water, and is a very inert substance; and I have raised a luxuriant crop of cresses in a soil composed of one-fifth carbonate of iron, and four-fifths carbonate of lime. Carbonate

of iron abounds in some of the most fertile soils in England, particularly the red hop soil. And there is no theoretical ground for supposing, that carbonic acid, which is an essential food of plants, should in any of its combinations be poisonous to them;* and it is known that lime and magnesia are both noxious to vegetation, unless combined with this principle.

All soils that contain too much dead vegetable fibre, and which consequently lose from one-third to one-half of their weight by incineration, and all such as contain their earthy constituents in an impalpable state of division, *i. e.* the stiff clays and marls, are improved by burning; but in coarse sands, or rich soils containing a just mixture of the earths; and in all cases in which the texture is already sufficiently loose, or the organisable matter sufficiently soluble, the process of torrefaction cannot be useful.

All poor siliceous sands must be injured by it; and here practice is found to accord with theory. Mr Young, in his Essay on Manures, states, "that he found burning injure sand;" and the operation is never performed by good agriculturists upon siliceous sandy soils, after they have once been brought into cultivation.

An intelligent farmer in Mount's Bay told me, that he had pared and burned a small field several years ago, which he had not been able to bring again into good condition. I examined the spot, the grass was very poor and scanty, and the soil an arid siliceous sand. †

Irrigation or *watering land*, is a practice, which at first view, appears the reverse of torrefaction; and in general, in nature, the operation of water is to bring earthy substances into an extreme state of division. But in the artificial watering of meadows, the beneficial effects depend upon many different causes, some chemical, some mechanical.

Water is absolutely essential to vegetation; and when land has been covered by water in the winter, or in the beginning of spring, the moisture that has penetrated deep into the soil, and even the subsoil, becomes a source of nourishment to the roots of the plant in the summer, and prevents those bad effects that often happen in lands in their natural state, from a long continuance of dry weather.

When the water used in irrigation has flowed over a calcareous country,

* The difference of opinion in this passage is at once explained when we distinguish between the carbonate of iron, properly so called, and the old inert carbonate of the shops, which was merely a peroxide. Peroxide of iron does not combine with carbonic acid, and is insoluble in water containing that substance. Protocarbonate, however, is soluble in excess of carbonic acid, and it is as such that iron generally occurs in chalybeate waters. Carbonate of iron is frequently found in subsoils, in certain blue clays, and in the water that runs from recently drained peat, marsh, and heath lands, and is poisonous to plants. On exposure to the air, however, the iron passes into the state of hydrated peroxide; which, unless when present in a soil to such an extent as to give it too light and puffy a texture, is by no means injurious to plants.

† This method of improving land ought to be had recourse to only when there is a superabundance of inert vegetable matter on the surface, as in the case of drained marsh or peat. It has often, notwithstanding the warnings given by Davy, been applied to thin heath land, where the little organic matter present could ill be spared. In such cases, especially where the burning has been followed by over-cropping, it is not to be wondered at that the land has become utterly worthless. It is far better to induce healthy decay on the inert organic matter of heath by lime and manure, than to have recourse to so wasteful a process as burning.

it is generally found impregnated with carbonate of lime; and in this state it tends, in many instances, to ameliorate the soil.

Common river water also generally contains a certain portion of organisable matter, which is much greater after rains than at other times; and which exists in the largest quantity when the stream rises in a cultivated country.

Even in cases when the water used for flooding is pure, and free from animal or vegetable substances, it acts by causing the more equable diffusion of nutritive matter existing in the land; and in very cold seasons it preserves the tender roots and leaves of the grass from being affected by frost.

Water is of greater specific gravity at 42° Fahrenheit, than at 32°, the freezing point; and hence in a meadow irrigated in winter, the water immediately in contact with the grass is rarely below 40°, a degree of temperature not at all prejudicial to the living organs of plants.

In 1804, in the month of March, I examined the temperature in a water meadow near Hungerford, in Berkshire, by a very delicate thermometer. The temperature of the air at seven in the morning was 29°. The water was frozen above the grass. The temperature of the soil below the water in which the roots of the grass were fixed, was 43°.

In general those waters which breed the best fish are the best fitted for watering meadows; but most of the benefits of irrigation may be derived from any kind of water. It is, however, a general principle, that waters containing ferruginous impregnations, though possessed of fertilising effects, when applied to a calcareous soil, are injurious on soils that do not effervesce with acids; and that calcareous waters which are known by the earthy deposit they afford when boiled, are of most use on siliceous soils, or other soils containing no remarkable quantity of carbonate of lime. *

* A distinction should be made between warping and irrigation. In the former it is the silt and solid matter deposited by the muddy water that is the means of enriching the soil, in the latter it is the water and whatever it holds in solution. In the former case the water is allowed to stagnate till it deposits its solid matter, in the latter it must be kept in constant motion; and that stagnation in the subsoil may be avoided, the first step in the process of preparing land for irrigation is to drain it with uncommon care. Liebig points out that it is the air, particularly the oxygen, that running water contains that is the great means of improving irrigated land, producing decay in the organic matter of the soil. "It is," he says, "because the water of rivers and streams contains oxygen in solution that it effects the most complete and rapid putrefaction of the excrements contained in the soil which it penetrates, and in which it is continually renewed. If it was the water alone which produced this effect, marshy meadows should be most fertile. Hence it is not sufficient in irrigating meadows to convert them into marshes, by covering, for several months, their surface with water, which is not renewed; for the advantage of irrigation consists principally in supplying oxygen to the roots of plants. The quantity of water necessary for this purpose is very small, so that it is sufficient to cover the meadow with a very thin layer, if this be frequently renewed." The dissolved oxygen would thus appear to be the means of keeping the soil of the meadows in a state fit for the continued growth of the same species of grasses. The carbonic acid and saline matters contained in the water are also liberally supplied to the plants. More accurate analyses than any hitherto made of water before and after irrigation are highly desirable. Little stress is now laid on the explanation given in the text, that the water protects the plants from frost, for it is well known that it is only in deep or stagnant water that there is much difference between the temperature of the top and bottom strata; and besides, on the approach of frost, irrigated meadows must be laid dry otherwise the grass would be injured.

The most important processes for improving land, are those which have been already discussed, and that are founded upon the circumstance of removing certain constituents from the soil, or adding others or changing their nature: but there is an operation of very ancient practice still much employed, in which the soil is exposed to the air, and submitted to processes which are purely mechanical, namely, *fallowing*.

The benefits arising from fallows have been much over-rated. A summer fallow, or a clean fallow, may be sometimes necessary in lands overgrown with weeds, particularly if they are sands, which cannot be pared and burnt with advantage; but is certainly unprofitable as part of a general system in husbandry.

It has been supposed by some writers, that certain principles necessary to fertility are derived from the atmosphere, which are exhausted by a succession of crops, and that these are again supplied during the repose of the land, and the exposure of the pulverised soil to the influence of the air; but this in truth is not the case. The earths commonly found in soils cannot be combined with more oxygen; none of them unite to azote; and such of them as are capable of attracting carbonic acid, are always saturated with it in those soils on which the practice of fallowing is adopted. The vague ancient opinion of the use of nitre, and of nitrous salts in vegetation, seems to have been one of the principal speculative reasons for the defence of summer fallows. Nitrous salts are produced during the exposure of soils containing vegetable and animal remains, and in greatest abundance in hot weather; but it is probably by the combination of azote from these remains with oxygen in the atmosphere that the acid is formed; and at the expense of an element, which otherwise would have formed ammonia; the compounds of which, as is evident from what was stated in the last Lecture, are much more efficacious than the nitrous compounds in assisting vegetation.

When weeds are buried in the soil, by their gradual decomposition they furnish a certain quantity of soluble matter; but it may be doubted whether there is as much useful manure in the land at the end of a clean fallow, as at the time the vegetables clothing the surface were first ploughed in. Carbonic acid gas is formed during the whole time by the action of the vegetable matter upon the oxygen of the air, and the greater part of it is lost to the soil in which it was formed, and dissipated in the atmosphere.

The action of the sun upon the surface of the soil tends to disengage the gaseous and the volatile fluid matters that it contains; and heat increases the rapidity of fermentation: and in the summer fallow, nourishment is rapidly produced, at a time when no vegetables are present capable of absorbing it. *

* Excepting on stiff and wet clays the method of summer fallowing has to a great extent given place to the cultivation of turnips, beet-root, potatoes, and such root-crops as are cultivated in drills. Although these root-crops prefer friable loams and porous soils, yet by thorough drainage, and the use of improved implements of tillage, such as the clod-crusher, many soils that formerly were fallowed are now made to produce fallow-crops; thus saving a year out of four without material deterioration to the other crops of the rotation, and at the same time producing a large quantity of farm-yard dung. During the growth of grain-crops that recur so frequently on stiff soils, weeds spring up, and partly by shedding their seeds before the reaping of the grain-crop, and partly by the extension of the roots of perennial species, accumulate to such an extent as to demand a great deal of tillage to extirpate them effectually. Whenever

Land, when it is not employed in preparing food for animals, should be applied to the purpose of the preparation of manure for plants; and this is effected by means of green crops, in consequence of the absorption of carbonaceous matter in the carbonic acid of the atmosphere. In a summer's fallow a period is always lost in which vegetables may be raised, either as food for animals, or as nourishment for the next crop; and the texture of the soil is not so much improved by its exposure as in winter, when the expansive powers of ice, the gradual dissolution of snows, and the alternations from wet to dry, tend to pulverize it, and to mix its different parts together.

In the drill husbandry the land is preserved clean by the extirpation of the weeds by hand, and by raising the crops in rows, which renders the destruction of the weeds much more easy. Manure is supplied either by the green crops themselves, or from the dung of the cattle fed upon them; and the plants having large systems of leaves, are made to alternate with those bearing grain.

It is a great advantage in the convertible system of cultivation, that the whole of the manure is employed; and that those parts of it which are not fitted for one crop, remain as nourishment for another. Thus, in Mr. Coke's course of Crops, the turnip is the first in the order of succession; and this crop is manured with recent dung, which immediately affords

the soil will at all admit of the cultivation of root-crops, the weeds may be destroyed during the preparation of the land for these crops, and by the subsequent hoeing and tillage that the cultivation of fallow-crops in drills so well admits of. Cases, however, may occur where, from carelessness or mismanagement, land capable of producing root-crops becomes so infested with weeds as to require a whole summer's fallow to clean the land effectually.

Liebig has shewn, in the most satisfactory manner, that the principal functions of fallowing are, by promoting the decomposition of the mineral matters of the soil, to afford a supply of the inorganic matter of which the soil is deprived by the exportation of grain and cattle from the farm; and, secondly, by promoting putrefaction and decay of the secretions given out by the roots of plants to permit of the recurrence of the same species at shorter intervals. The first of these positions no one disputes. It is obvious that, when all the marketable grain and fat cattle are sold off a farm, the fields must be robbed of certain inorganic principles, alkalies and phosphates for instance, that must be replaced in the shape of extraneous manures, provided they cannot be produced by the decomposition of mineral matter in the soil, and by a decomposition too, that keeps pace with the wants of the crops cultivated. Now, although most clay soils contain mineral matter capable of affording the alkalies at least, yet, on account of their close texture, and the consequent exclusion of water and atmospheric influences, the decomposition is slow, and requires to be aided by the frequent ploughings, harrowings, and grubbings of the fallow. As to the second of these positions, there is much difference of opinion, many denying that plants have the power of excretion by the roots. It appears, however, to be satisfactorily established that healthy aquatic plants colour the water in which they grow, and that plants grown in charcoal impart to it organic matter soluble in dilute alkaline solutions, which the charcoal did not originally contain, and which can be satisfactorily accounted for only on the supposition of its being matter secreted by the plant. If this is the case, it is obvious, as Liebig shews, that secreted matter cannot prove nutritive to plants, for if taken up it could not be assimilated, and its accumulation in the soil must concur with the exhaustion of inorganic matter in deteriorating crops following in immediate succession or recurring at short intervals. The operations of the fallow, however, by causing decomposition of the excretions of plants, render these substances useful in supplying carbonic acid as a product of their decay.

sufficient soluble matter for its nourishment; and the heat produced in fermentation assists the germination of the seed and the growth of the plant. After turnips, barley with grass seeds is sown; and the land having been little exhausted by the turnip crop, affords the soluble parts of the decomposing manure to the grain. The grasses, rye-grass, and clover remain, which derive a small part only of their organised matter from the soil, and probably consume the gypsum in the manure which would be useless to other crops: these plants likewise, by their large systems of leaves, absorb a considerable quantity of nourishment from the atmosphere; and when ploughed in at the end of two years, the decay of their roots and leaves affords manure for the wheat crop; and at this period of the course, the woody fibre of the farm-yard manure which contains the phosphate of lime and the other difficultly soluble parts, is broken down and as soon as the most exhausting crop is taken, recent manure is again applied.

Mr Gregg, whose very enlightened system of cultivation has been published by the Board of Agriculture, and who has the merit of first adopting a plan similar to Mr Coke's upon strong clays, suffers the ground after barley to remain at rest for two years in grass; sows peas and beans on the leys; ploughs in the pea or bean stubble for wheat; and in some instances, follows his wheat crops by a course of winter tares and winter barley, which is eat off in the spring, before the land is sowed for turnips.

Peas and beans, in all instances, seem well adapted to prepare the ground for wheat; and in some rich lands, as in the alluvial soil of the Parret, mentioned in the fourth Lecture, and at the foot of the South Downs in Sussex, they are raised in alternate crops for years together. Peas and beans contain, as appears from the analyses in the third Lecture, a small quantity of a matter analogous to albumen; but it seems that the azote, which forms a constituent part of this matter, is derived from the atmosphere. The dry bean leaf, when burnt, yields a smell approaching to that of decomposing animal matter; and in its decay in the soil, may furnish principles capable of becoming a part of the gluten in wheat.

Though the general composition of plants is very analogous, yet the specific difference in the products of many of them, and the facts stated in the last Lecture, prove that they must derive different materials from the soil; and though the vegetables having the smallest systems of leaves will proportionably most exhaust the soil of common nutritive matter, yet particular vegetables, when their produce is carried off, will require peculiar principles to be supplied to the land in which they grow, Strawberries and potatoes at first produce luxuriantly in virgin mould recently turned up from pasture; but in a few years they degenerate, and require a fresh soil; and the organization of these plants is such, as to be constantly producing the migration of their layers: thus the strawberry by its long shoots is constantly endeavouring to occupy a new soil; and the fibrous radicles of the potato produce bulbs at a considerable distance from the parent plant. Lands in a course of years often cease to afford good cultivated grasses; they become (as it is popularly said) tired of them; and one or the probable reasons for this was stated in the last Lecture. *

The most remarkable instance of the powers of vegetables to exhaust the soil of certain principles necessary to their growth is found in certain funguses. Mushrooms are said never to rise in two successive seasons on the same spot; and the production of the phenomena called fairy rings

* See note, page 163.

has been ascribed by Dr. Wollaston to the power of the peculiar fungus which forms it to exhaust the soil of the nutriment necessary for the growth of the species. The consequence is, that the ring annually extends; for no seeds will grow where their parents grew before them; and the interior part of the circle has been exhausted by preceding crops; but where the fungus has died, nourishment is supplied for grass, which usually rises within the circle, coarse, and of a dark green colour.

When cattle are fed upon land not benefitted by their manure, the effect is always an exhaustion of the soil; this is particularly the case where carrying horses are kept on estates; they consume the pasture during the night, and drop the greatest part of their manure during their labour in the day-time.

The exportation of grain from a country, unless some articles capable of becoming manure are introduced in compensation, must ultimately tend to exhaust the soil. Some of the spots now desert sands in northern Africa, and Asia Minor, were anciently fertile. Sicily was the granary of Italy: and the quantity of corn carried off from it by the Romans, is probably a chief cause of its present sterility. In this Island, our commercial system at present has the effect of affording substances, which, in their use and decomposition, must enrich the land. Corn, sugar, tallow, oil, skins, furs, wine, silk, cotton, &c., are imported, and fish are supplied from the sea. Amongst our numerous exports, woollen, and linen, and leather goods, are almost the only substances which contain any nutritive materials derived from the soil.

In all courses of crops it is necessary that every part of the soil should be made as useful as possible to the different plants; but the depth of the furrow in ploughing must depend upon the nature of the soil, and of the subsoil. In rich clayey soils the furrow can scarcely be too deep; and even in sands, unless the subsoil contains some principles noxious to vegetables, the same practice should be adopted. When the roots are deep they are less liable to be injured, either by excess of rain, or drought; the layers shoot forth their radicles into every part of the soil; and the space from which the nourishment is derived is more considerable, than when the seed is superficially inserted in the soil.

There has been much difference of opinion with respect to permanent pasture; but the advantages or disadvantages can only be reasoned upon according to the circumstances of situation and climate. Under the circumstances of irrigation, lands are extremely productive, with comparatively little labour: and in climates where great quantities of rain falls, the natural irrigation produces the same effects as artificial. When hay is in great demand, as sometimes happens in the neighbourhood of the metropolis, where manure can be easily procured, the application of it to pasture is repaid for by the increase of crop; but top-dressing grass land with animal or vegetable manure, cannot be recommended as a general system. Dr. Coventry very justly observes, that there is a greater waste of the manure in this case, than when it is ploughed into the soil for seed crops. The loss by exposure to the air, and the sunshine, offer reasons in addition to those that have been already quoted in the sixth Lecture, for the application of manure even in this case, in a state of incipient, and not completed fermentation.

Very little attention has been paid to the nature of the grasses best adapted for permanent pasture. The chief circumstance which gives value to a grass, is the quantity of nutritive matter that the whole crop will afford; but the time and duration of its produce are likewise points

of great importance; and a grass that supplies green nutriment throughout the whole of the year, may be more valuable than a grass which yields its produce only in summer, though the whole quantity of food supplied by it should be much less.

The grasses that propagate themselves by layers, the different species of Agrostis, supply pasture throughout the year; and, as it has been mentioned on a former occasion, the concrete sap stored up in their joints, renders them a good food even in winter. I saw four square yards of fiorin grass cut in the end of January, this year, in a meadow exclusively appropriated to the cultivation of fiorin, by the Countess of Hardwicke, the soil of which is a damp stiff clay. They afforded 28 lbs. of fodder; of which 1000 parts afforded 64 parts of nutritive matter, consisting nearly of one-sixth of sugar, and five-sixths of mucilage, with a little extractive matter. In another experiment, four square yards gave 27 pounds of grass. The quality of this grass is inferior to that of the fiorin referred to in the Table, in the latter part of the Third Lecture, which was cultivated by Sir Joseph Banks in Middlesex, in a much richer soil, and cut in December.

The fiorin grass, to be in perfection, requires a moist climate or a wet soil; and it grows luxuriantly in cold clays unfitted for other grasses. In light sands, and in dry situations, its produce is much inferior as to quantity and quality.

The common grasses, properly so called, that afford most nutritive matter in early spring, are the vernal meadow grass, and meadow foxtail grass; but their produce at the time of flowering and ripening the seed, are inferior to that of a great number of other grasses; their latter-math is, however, abundant.

Tall fescue grass stands highest, according to the experiments of the Duke of Bedford, of any grass, properly so called, as to the quantity of nutritive matter afforded by the whole crop when cut at the time of flowering; and meadow cat's-tail grass affords most food when cut at the time the seed is ripe; the highest latter-math produce of the grasses examined in the Duke of Bedford's experiments is from the sea meadow grass.

Nature has provided in all permanent pastures a mixture of various grasses, the produce of which differs at different seasons. Where pastures are to be made artificially, such a mixture ought to be imitated; and, perhaps, pastures superior to the natural ones may be made by selecting due proportions of those species of grasses fitted for the soil, which afford respectively the greatest quantities of spring, summer, latter-math, and winter produce; a reference to the details in the Appendix will shew, that such a plan of cultivation is very practicable. *

* The appendix here referred to has been omitted in the present edition because it appeared to the Editor, that however carefully the experiments were conducted different soils being used, they could not be comparative; and the size of the plots (4 square feet), was too small to afford satisfactory results as to the quantity of produce. The method, moreover, of determining the nutritive values of the different plants, although perhaps the best in use at the time, would not, in the present day, be received as accurate or conclusive.

In laying down permanent pasture, attention should be given to several points, some of which may be mentioned.

1st. That the species be suitable to the soil and climate. This kind of information is best obtained by studying the soils and situations where the different species occur naturally.

2nd. That species that flower and come to maturity at different periods should

In all lands whether arable or pasture, weeds of every description should be rooted out before the seed is ripe; and if they are suffered to remain in hedge-rows, they should be cut when in flower, or before, and made into heaps for manure; in this case they will furnish more nutritive matter in their decomposition; and their increase by the dispersion of seeds will be prevented. The farmer, who suffers weeds to remain till their ripe seeds are shed, and scattered by the winds, is not only hostile to his own interests, but is likewise an enemy to the public: a few thistles will stock a whole farm; and by the light down which is attached to their seeds, they may be distributed over a whole country. Nature has provided such ample resources for the continuance of even the meanest vegetable tribes, that it is very difficult to ensure the destruction of such as are hostile to the agriculturist, even with every precaution. Seeds excluded from the

be sown together, that the pasture may be green throughout the season, and at all times afford a bite.

3rd. That species relished by the sort of stock to be kept on the pastures should be selected. It is well known that sheep, oxen, and horses, shew different preferences as to some species of grass.

4th. That permanent species should be preferred. Rye-grass and red clover do not last in permanent pasture, but it is proper, nevertheless, to sow them, for they give abundant food the first two years, while some of the more lasting species require two or three years to come to vigorous growth.

5th. Many grasses with creeping roots, and certain others, such as the *Alopecurus pratensis*, the *Phleum pratense* and the *Festuca pratensis*, that are not so well suited to the alternate husbandry, on account of their roots not decaying readily when the lea is broken up, are very valuable for permanent pasture.

In the alternate husbandry, when the course is a four years one, it is usual to employ only red clover, (*Trifolium pratense*,) and the so-called annual rye-grass. (*Lolium Italicum.*) The annual rye-grass is preferred to the perennial, because it yields a considerably greater weight of hay. When the grass is to last two or three years, as in the five, six, and seven year's rotations, the annual rye-grass is inadmissible, and of late years much serious loss has arisen in all parts of Scotland from the annual being sold for the perennial. The plants are not difficult to distinguish, but it is impossible or extremely difficult to distinguish the seeds. Perhaps the best way of obviating the difficulty is never to sow seed but from second year's grass, and it is the more certain to contain no annual seed that the same grass had the previous year been cut as hay. Another advantage of using seed from second year's grass is that it secures the absence of the soft brome grass, (*Bromus molis*,) which, like the *Lolium Italicum*, is a biennial, and although it weighs well, is a coarse grass, and not relished by horses among hay.

When grass is required to last three years, that is to say, when it is cut as hay the first year, and depastured the two following ones, so little rye-grass and clover keep the ground till the third year, that it is always advisable to sow some other species along with them. Circumstances will determine the selection of species, but the following may be mentioned as very generally useful:—*Poa trivialis, P. pratensis, Dactylis glomerata, Festuca duriuscula, Cynosurus cristatus.* It frequently happens when the grain-crop with which the grass seeds are sown down, is a heavy one, and gets lodged, or when the *stooks* stand long on the field, that the grass on these parts is completely destroyed, and weeds spring up in the blanks. To prevent this I have seen the *Poa annua*, a small but very nutritive and rapidly growing grass sown on the blanks with great advantage. The seeds of this grass are not always to be procured from the seedsmen, but with a little attention it is not difficult to raise them, and the farmer will often find it useful to do so.

air, will remain for years inactive in the soil,* and yet germinate under favourable circumstances; and the different plants, the seeds of which, like those of the thistle and dandelion, are furnished with beards or wings, may be brought from an immense distance. The fleabane of Canada has only lately been found in Europe; and Linnæus supposes, that it has been transported from America, by the very light downy plumes with which the seed is provided.

In feeding cattle with green food there are many advantages in *soiling*, or supplying them with food, where their manure is preserved, out of the field; the plants are less injured when cut, than when torn or jagged by the teeth of the cattle, and no food is wasted by being trodden down. They are likewise obliged to feed without making selection; and in consequence the whole food is consumed: the attachment, or dislike to a particular kind of food exhibited by animals, offers no proof of its nutritive powers. Cattle, at first, refuse linseed cake, one of the most nutritive substances on which they can be fed.†

* The appearance of seeds in places where their parent plants are not found, may be easily accounted for from this circumstance, and other circumstances. Many seeds are carried from island to island by currents in the sea, and are defended by their hard coats from the immediate action of the water. West Indian seeds (of this description) are often found on our coasts, and readily germinate; their long voyage having been barely sufficient to afford the cotyledon its due proportion of moisture. Other seeds are carried indigested in the stomach of birds, and supplied with food at the moment of their deposition. The light seeds of the mosses and lichens, probably float in every part of the atmosphere and abound on the surface of the sea.—D.

† For the following observations on the selection of different kinds of common food by sheep and cattle, I am obliged to Mr George Sinclair.—D.

"*Lolium perenne*, rye-grass. Sheep eat this grass when it is in the early stage of its growth, in preference to most others; but after the seed approaches towards perfection, they leave it for almost any other kind. A field in the Park at Woburn was laid down in two equal parts, one part with rye-grass and white clover, and the other part with cock's-foot and red clover: from the spring till midsummer the sheep kept almost constantly on the rye-grass; but after that time they left it, and adhered with equal constancy to the cock's-foot during the remainder of the season.

Dactylis glomerata, cock's-foot. Oxen, horses, and sheep, eat this grass readily. The oxen continue to eat the straws and flowers, from the time of flowering, till the time of perfecting the seed; this was exemplified in a striking manner in the field before alluded to. The oxen generally kept to the cock's-foot and red clover, and the sheep to the rye-grass and white clover. In the experiments published in the Amœnitates Academicæ, by the pupils of Linnæus, it is asserted, that this grass is rejected by oxen; the above fact, however, is in contradiction of it.

Alopecurus pratensis, meadow fox-tail. Sheep and horses seem to have a greater relish for this grass than oxen. It delights in a soil of intermediate quality as to moisture or dryness, and is very productive. In the water-meadow at Priestley, it constitutes a considerable part of the produce of that excellent meadow. It there keeps invariably possession of the top of the ridges, extending generally about six feet from each side of the water course; the space below that, to where the ridge ends, is stocked with cock's-foot, the rough stalked meadow grass, *Festuca pratensis*, *Festuca duriuscula*, *Agrostis stolonifera*, *Agrostis palustris*, and sweet-scented vernal grass, with a small admixture of some other kinds.

Phleum pratense, meadow cat's-tail. This grass is eaten without reserve, by oxen, sheep, and horses. Dr. Pulteney says, that it is disliked by sheep; but in pastures where it abounds, it does not appear to be rejected by these animals; but eaten in common with such others as are growing with it. Hares are

When food artificially composed is to be given to cattle, it should be brought as nearly as possible to the state of natural food. Thus, when sugar is given to them, some dry fibrous matter should be mixed with it, such as chopped straw, or dry withered grass, in order that the functions of the stomach and bowels may be performed in a natural manner. The principle is the same as that of the practice alluded to in the Third Lecture, of giving choped straw with barley.

In washing sheep, the use of water containing carbonate of lime should

remarkably fond of it. The *Phleum nodosum*, *Phleum alpinum*, *Poa fertilis*, and *Poa compressa*, were left untouched, although they were closely adjoining to it. It seems to attain the greatest perfection in a rich deep loam.

Agrostis stolonifera, fiorin. In the experiments detailed in the Amœnitates Academicæ, it is said, that horses, sheep, and oxen, eat this grass readily. On the Duke of Bedford's farm at Maulden, fiorin hay was placed in the racks before horses in small distinct quantities, alternately with common hay; but no decided preference for either, was manifested by the horses in this trial. But that cows and horses prefer it to hay, when in a green state, seems fully proved by Dr. Richardson, in his several publications on Fiorin; and of its productive powers in England (which has been doubted by some,) there are satisfactory proofs. Lady Hardwick has given an account of a trial of this grass; wherein 23 milch cows, and one young horse, besides a number of pigs, were kept a fortnight on the produce of one acre.

Poa trivialis, rough-stalked meadow. Oxen, horses, and sheep, eat this grass with avidity. Hares also eat it; but they give a decided preference to the smooth-stalked meadow grass, to which it is, in many respects, nearly allied.

Poa pratensis, smooth-stalked meadow grass. Oxen and horses, are observed to eat this grass in common with others; but sheep rather prefer the hard fescue, and sheeps' fescue, which affect a similar soil. This species exhausts the soil in a greater degree, than almost any other species of grass; the roots being numerous, and powerfully creeping, become in two or three years completely matted together; the produce diminishes as this takes place. It grows common in some meadows, dry banks, and even on walls.

Cynosurus cristatus, crested dog's-tail grass. The South Down sheep, and deer, appear to be remarkably fond of this grass; in some parts of Woburn Park this grass forms the principal part of the herbage on which these animals chiefly browse; while another part of the park, that contains the *Agrostis capillaris*, *Agrostis pumilis*, *Festuca ovina*, *Festuca duriuscula*, and *Festuca cambrica*, is seldom touched by them; but the Welsh breed of sheep almost constantly browse upon these, and neglect the *Cynosurus cristatus*, *Lolium perenne*, and *Poa trivialis*.

Agrostis vulgaris (*capillaris* Linn.), fine bent; common bent. This is a very common grass on all poor dry sandy soils. It is not palatable to cattle, as they never eat it readily, if any other kinds be within their reach. The Welsh sheep, however, prefer it, as I before observed; and it is singular, that those sheep being bred in the park, when some of the best grasses are equally within their reach, should still prefer those grasses which naturally grow on the Welsh mountains: it seems to argue that such a preference is the effect of some other cause, than that of habit.

Festuca ovina, sheeps' fescue. All kinds of cattle relish this grass; but it appears from the trial that has been made with it on clayey soils, that it continues but a short time in possession of such, being soon overpowered by the more luxuriant kinds. On dry shallow soils that are incapable of producing the larger sorts, this should form the principal crop, or rather the whole; for it is seldom or ever, in its natural state, found intimately mixed with others; but by itself.

Festuca duriuscula, hard fescue grass. This is certainly one of the best of the dwarf sort of grasses. It is grateful to all kinds of cattle; hares are very fond of it: they cropped it close to the roots, and neglected the *Festuca ovina*,

be avoided; for this substance decomposes the yolk of the wool, which is an animal soap, the natural defence of the wool; and wool often washed in calcareous water, becomes rough and more brittle. The finest wool, such as that of the Spanish and Saxon sheep, is most abundant in yolk. M. Vauquelin has analysed several different species of yolk, and has found the principal part of all of them a soap, with a basis of potassa, *i. e.* a compound of oily matter and potassa, with a little oily matter in excess. He has found in them, likewise, a notable quantity of acetate of potassa, and minute quantities of carbonate of potassa and muriate of potassa, and a peculiar odorous animal matter.

M. Vauquelin states, that he found some specimens of wool lose as much as 45 per cent. in being deprived of their yolk; and the smallest loss in his experiments was 35 per cent.

The yolk is most useful to the wool on the back of the sheep in cold and wet seasons; probably the application of a little soap of potassa, with excess of grease to the sheep brought from warmer climates in our winter, that is, increasing their yolk artificially, might be useful in cases where the fineness of the wool is of great importance. A mixture of this kind is more conformable to nature, than that ingeniously adopted by Mr Bakewell; but at the time his labours commenced, the chemical nature of the yolk was unknown.

and *Festuca rubra*, which were contiguous to it. It is present in most good meadows and pastures.

Festuca pratensis, meadow fescue. This grass is seldom absent from rich meadows and pastures; it is observed to be highly grateful to oxen, sheep, and horses, particularly the former. It appears to grow most luxuriantly when combined with the hard fescue, and *Poa trivialis*.

Avena eliator, tall oat grass. This is a very productive grass, frequent in meadows and pastures, but is disliked by cattle, particularly by horses; this perfectly agrees with the small portion of nutritive matter which it affords. It seems to thrive best on a strong tenacious clay.

Avena flavescens, yellow oat-grass. This grass seems partial to dry soils, and meadows, and appears to be eaten by sheep and oxen, equally with the meadow barley, crested dog's-tail, and sweet-scented vernal grasses, which naturally grow in company with it. It nearly doubles the quantity of its produce by the application of calcareous manure.

Holcus lanatus, meadow soft grass. This is a very common grass, and grows on all soils, from the richest to the poorest. It affords an abundance of seed, which is light, and easily dispersed by the wind. It appears to be generally disliked by all sorts of cattle. The produce is not so great as a view of it in fields would indicate; but being left almost entirely untouched by cattle, it appears as the most productive part of the herbage. The hay which is made of it, from the number of downy hairs which cover the surface of the leaves, is soft and spongy, and disliked by cattle in general.

Anthoxanthum odoratum, sweet-scented vernal grass. Horses, oxen, and sheep, eat this grass; though in pastures where it is combined with the meadow foxtail, and white clover, cock's-foot, rough stalked meadow, it is left untouched, from which it would seem unpalatable to cattle. Mr Grant, of Leighton, laid down one-half of a field of considerable extent with this grass, combined with white clover. The other half of the field with fox-tail and red clover. The sheep would not touch the sweet-scented vernal, but kept constantly upon the fox-tail. The writer of this saw the field when the grasses were in the highest state of perfection; and hardly anything could be more satisfactory. Equal quantities of the seeds of white clover were sown with each of the grasses; but from the dwarf nature of the sweet-scented vernal grass, the clover mixed with it had attained to greater luxuriance than that mixed with the meadow fox-tail."

I have now exhausted all the subjects of discussion, which my experience or information have been able to supply on the connection of chemistry with agriculture.

I venture to hope, that some of the views brought forward, may contribute to the improvement of the most important and useful of the arts.

I trust that the inquiry will be pursued by others; and that in proportion as chemical philosophy advances towards perfection, it will afford new aids to agriculture.

There are sufficient motives connected both with pleasure and profit, to encourage ingenious men to pursue this new path of investigation. Science cannot long be despised by any persons as the mere speculation of theorists; but must soon be considered by all ranks of men in its true point of view, as the refinement of common sense, guided by experience, gradually substituting sound and rational principles, for vague popular prejudices.

The soil offers inexhaustible resources, which, when properly appreciated and employed, must increase our wealth, our population, and our physical strength.

We possess advantages in the use of machinery, and the division of labour, belonging to no other nation. And the same energy of character, the same extent of resources which have always distinguished the people of the British Islands, and made them excel in arms, commerce, letters, and philosophy, apply with the happiest effect to the improvement of the cultivation of the earth. Nothing is impossible to labour, aided by ingenuity. The true objects of the agriculturist are likewise those of the patriot. Men value most what they have gained with effort; a just confidence in their own powers results from success; they love their country better, because they have seen it improved by their own talents and industry; and they identify with their interests, the existence of those institutions which have afforded them security, independence, and the multiplied enjoyments of civilized life.

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EXPERIMENTAL RESEARCHES

IN

ELECTRO-CHEMISTRY,

INCLUDING

THE BAKERIAN LECTURES, AND MEMOIRS READ BEFORE THE ROYAL SOCIETY, IN THE YEARS 1806, 1807, AND 1808,

ON THE

CHEMICAL AGENCIES OF ELECTRICITY,

AND ON THE

METALS OF THE ALKALIES AND EARTHS.

BY

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Read before the Royal Society, November 20, 1806.
Published in the Philosophical Transactions for the year 1807.

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EXPERIMENTAL RESEARCHES

IN

CHEMISTRY.

I.

THE BAKERIAN LECTURE FOR 1806.

ON SOME CHEMICAL AGENCIES OF ELECTRICITY.

Read before the Royal Society, November 20, 1806.

PUBLISHED IN THE PHILOSOPHICAL TRANSACTIONS FOR THE YEAR 1807.

I.—INTRODUCTION.

THE chemical effects produced by electricity have been for some time objects of philosophical attention; but the novelty of the phenomena, their want of analogy to known facts, and the apparent discordance of some of the results, have involved the inquiry in much obscurity.

An attempt to elucidate the subject will not, I hope, be considered by the Society as unfitted to the design of the Bakerian Lecture. I shall have to detail some minute (and I fear tedious) experiments; but they were absolutely essential to the investigation. I shall likewise, however, be able to offer some illustrations of appearances which hitherto have not been fully explained, and to point out some new properties of one of the most powerful and general of material agents.

II.—ON THE CHANGES PRODUCED BY ELECTRICITY IN WATER.

The appearance of acid and alkaline matter in water acted on by a current of electricity, at the opposite electrified metallic surfaces was observed in the first chemical experiments made with the column of Volta.*

Mr. Cruickshank† supposed that the acid was the nitrous acid and the alkali ammonia. M. Desormes‡ soon after attempted to show by experiments, that muriatic acid and ammonia were the products, and M. Brugnatelli§ asserted the formation of a new and peculiar substance, which he has thought proper to call the electric acid. The experiments said to be made in Italy, and in this country, on the production of muriate of soda are recent,‖ and the discussions with regard to them still alive. As early as 1800, I had found that when separate portions of distilled water, filling two glass tubes connected by moist bladders, or any moist animal or vegetable substances, were submitted to the electrical action of the pile of Volta by means of gold wires, a nitro-muriatic solution of gold appeared in the tube containing the positive wire, or the wire transmitting the electricity, and a solution of soda in the opposite tube;* but I soon ascertained that the muriatic acid owed its appearance to the animal or vegetable matters employed; for when

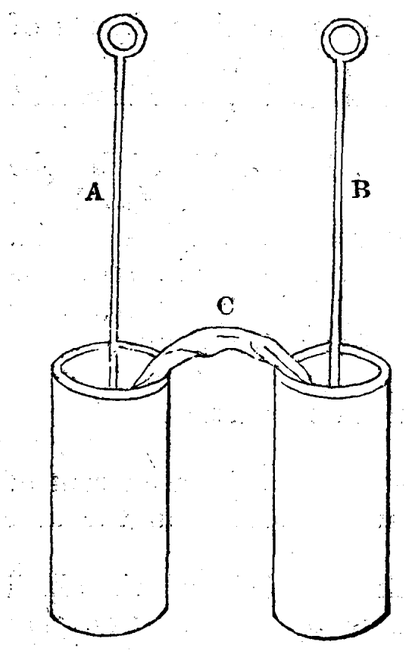
* Nicholson's Journal, 4to vol. iv. p. 183.
† Ibid. vol. iv. p. 261.
‡ Annales de Chimie, tom. xxxvii. p. 233.
§ Phil. Mag. vol. ix. p. 181
‖ By M. Pacchioni, and by Mr. Peele, Phil. Mag. vol. xxi. p. 279.

the same fibres of cotton were made use of in successive experiments, and washed after every process in a weak solution of nitric acid, the water in the apparatus containing them, though acted on for a great length of time with a very strong power, at last produced no effect upon solution of nitrate of silver.

In cases when I had procured much soda, the glass at its point of contact with the wire seemed considerably corroded; and I was confirmed in my idea of referring the production of the alkali principally to this source, by finding that no fixed saline matter could be obtained, by electrifying distilled water in a single agate cup from two points of platina connected with the Voltaic battery. Similar conclusions with regard to the appearance of the muriatic acid had been formed by the Galvanic Society of Paris, by Dr. Wollaston, who hit upon the happy expedient of connecting the tubes together by well washed asbestus; and by MM. Biot and Thenard.†

Mr. Sylvester, however, in a Paper published in Mr. Nicholson's Journal for last August, states, that though no fixed alkali or muriatic acid appears when a single vessel is employed; yet that they are both formed when two vessels are used. And to do away all objections with regard to vegetable substances or glass, he conducted his process in a vessel made of baked tobacco-pipe clay inserted in a crucible of platina. I have no doubt of the correctness of his results: but the conclusion appears objectionable. He conceives that he obtained fixed alkali, because the fluid after being heated and evaporated left a matter that tinged turmeric brown, which would have happened had it been lime, a substance that exists in considerable quantities in all pipe-clay; and even allowing the presence of fixed alkali, the materials employed for the manufacture of tobacco-pipes are not at all such as to exclude the combinations of this substance.

I resumed the inquiry; I procured small cylindrical cups of agate, of the capacity of about $\frac{1}{4}$ of a cubic inch each.‡ They were boiled for some hours in distilled water, and a piece of very white and transparent amianthus that had been treated in the same way was made to connect them together; they were filled with distilled water, and exposed by means of two platina wires to a current of electricity, from 150 pairs of plates of copper and zinc 4 inches square, made active by means of solution of alum. After 48 hours the process was examined; paper tinged with litmus plunged into the tube containing the transmitting or positive wire was immediately strongly reddened. Paper coloured by turmeric introduced into the other tube had its colour much deepened; the acid matter gave a very slight degree of turbidness to solution of nitrate of silver. The fluid that affected turmeric retained this property after being strongly boiled; and it appeared more vivid as the quantity became reduced by evaporation; carbonate of ammonia was mixed with it, and the whole dried and exposed to a strong heat; a minute quantity of white matter remained, which, as far as my examination could go, had the properties of carbonate of soda. I compared it with similar minute portions of the pure carbonates of potash and soda. It was not so deliquescent as the former of these bodies, and it formed a salt with nitric acid, which like nitrate of soda soon attracted moisture from a damp atmosphere, and became fluid.



This result was unexpected, but it was far from convincing me that the substances which I had obtained were *generated*. In a similar process, with glass tubes, carried on exactly under the same circumstances, and for the same time, I obtained a quantity of alkali which must have been more than twenty times greater,

* I showed the results of the experiment to Dr. Beddoes at this time; and mentioned the circumstance to Sir James Hall, Mr. Clayfield, and other friends, in 1801.

† No. XL. Du Moniteur, 1806

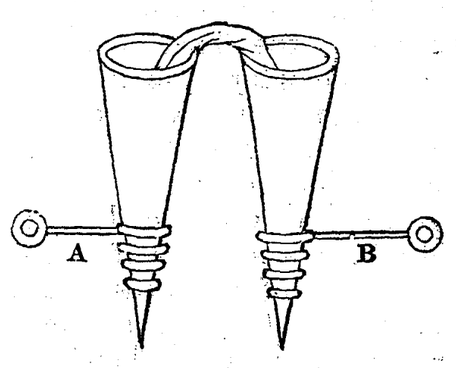
‡ In this and all the figures contained in the present article, A, B, denote the wires, rendered one positively, the other negatively electrical; and C, the connecting pieces of moistened amianthus.

but no traces of muriatic acid. There was much probability that the agate might contain some minute portion of saline matter, not easily detected by chemical analysis, either in combination, or intimate adhesion in its pores. To determine this, I repeated the experiment a second, a third, and a fourth time. In the second experiment turbidness was still produced by solution of nitrate of silver in the tube containing the acid, but it was less distinct; in the third process it was barely perceptible: and in the fourth the two fluids remained perfectly clear after the mixture. The quantity of alkaline matter diminished in every operation: and in the last process, though the battery had been kept in great activity for three days, the fluid possessed in a very slight degree only the power of acting on paper tinged with turmeric; but its alkaline property was very sensible to litmus paper slightly reddened, which is a much more delicate test: and after evaporation and the process by carbonate of ammonia, a barely perceptible quantity of fixed alkali was still left. The acid matter in the other tube was abundant; its taste was sour; it smelt like water over which large quantities of nitrous gas have been long kept; it did not affect solution of muriate of barytes; and a drop of it placed upon a polished plate of silver left after evaporation a black stain, precisely similar to that produced by extremely diluted nitrous acid.

After these results, I could no longer doubt that some saline matter existing in the agate tubes had been the source of the acid matter capable of precipitating nitrate of silver, and of much of the alkali. Four additional repetitions of the process, however, convinced me that there was likewise some other cause for the presence of this last substance; for it continued to appear to the last, in quantities sufficiently distinguishable, and apparently equal in every case. I had used every precaution; I had included the tubes in glass vessels out of the reach of the circulating air; all the acting materials had been repeatedly washed with distilled water; and no part of them in contact with the fluid had been touched by the fingers.

The only substance which I could now conceive capable of furnishing the fixed alkali was the *water itself.* This water appeared pure by the tests of nitrate of silver and muriate of barytes; but potash and soda, as is well known, rise in small quantities in rapid distillations; and the New River water, which I made use of, contains animal and vegetable impurities, which it was easy to conceive might furnish neutral salts capable of being carried over in vivid ebullition.

To make the experiment in as refined a form as possible, I procured two hollow cones of pure gold containing about 25 grains of water each; they were filled with distilled water, connected together by a moistened piece of amianthus which had been used in the former experiments, and exposed to the action of a Voltaic battery of 100 pairs of plates of copper and zinc of 6 inches square, in which the fluid was a solution of alum and diluted sulphuric acid. In ten minutes the water in the negative tube had gained the power of giving a slight blue tint to litmus paper: and the water in the positive tube rendered it red. The process was continued for 14 hours; the acid increased in quantity during the whole time, and the water became at last very sour to the taste. The alkaline properties of the fluid in the other tube, on the contrary, remained stationary, and at the end of the time, it did not act upon litmus or turmeric paper more than in the first trial: the effect was less vivid after it had been strongly heated for a minute; but evaporation and the usual process proved that *some* fixed alkali was present. The acid, as far as its properties were examined, agreed with pure nitrous acid, having an excess of nitrous gas.



I *repeated* the experiment, and carried on the process for three days; at the end of which time the water in the tube was decomposed and evaporated to more than one-half of its original quantity; the acid was strong, but the alkali in as minute a portion as in the last experiment. It acted indeed rather more vividly on the tests, on account of the greater diminution of the fluid, but presented the same results after being heated.

It was now impossible to doubt that the water contained some substance in

very minute quantities, capable of causing the appearance of fixed alkali, but which was soon exhausted; and the question that immediately presented itself was, Is this substance saline matter carried over in distillation? or is it nitrogen gas which exists in minute portions in all water that has been exposed to air, and which, if an element of the fixed alkali, would under the circumstances of the experiment have been soon exhausted, whilst its absorption from the atmosphere would be impeded by the saturation of the water with hydrogen?

I was much more inclined to the former than to the latter supposition. I evaporated a quart of the distilled water that I had used, very slowly at a heat below 140° Fahrenheit, in a silver still; a solid matter remained, equal to 7-10ths of a grain; this matter had a saline but metallic taste, and was deliquescent when exposed to air: I could not obtain from it regular crystals; it did not affect turmeric or litmus, but a part of it, after being heated red, in a silver crucible, exhibited strong alkaline properties. It was not possible to make a minute analysis of so small a quantity, but it appeared to me to be principally a mixture of nitrate of soda and nitrate of lead; and the metallic substance, it is most likely, was furnished by the condensing tube of the common still.

The existence of saline matter in the distilled water being thus distinct, it was easy to determine its operation in the experiment. I filled the two gold cones with water in the usual manner; that negatively electrified, soon attained the maximum of its effect upon turmeric paper. I then introduced into it a very minute portion of the substance obtained by the process of evaporation that has been just described; in less than two minutes its effects were evident; and in five minutes the tint of the paper was changed to a bright brown.

I now conceived that by collecting the water obtained in the second process of slow distillation I should be able to carry on the experiment without *any* appearance of fixed alkali, and the trial proved that I was not mistaken.

Some of this water was introduced into the gold tubes, and the amianthus moistened by it.

After two hours the water in the negative tube produced no effect upon turmeric paper; it did produce an effect upon litmus, which it required great minuteness of observation to perceive; but it wholly lost the power by being heated strongly for two or three minutes, so there is every reason for supposing that it was owing to a small quantity of ammonia.

I made a similar experiment with a portion of the same water in the tubes of agate that had been so often used, and I had the pleasure of finding the results precisely the same.

To detail any more operations of this kind will be unnecessary; all the facts prove that the fixed alkali is not *generated*, but *evolved*, either from the solid materials employed, or from saline matter in the water.

I have made many experiments in vessels composed of different substances, with the water procured by very slow distillation; and in almost every instance some fixed alkali appeared.

In tubes of wax the alkaline matter was a mixture of soda and potash; and the acid matter a mixture of sulphuric, muriatic, and nitric acids.

In a tube of resin, the alkaline matter seemed to be principally potash.

A cube of Carrara marble of about an inch, having an aperture in its centre, was placed in a crucible of platina, which was filled as high as the upper surface of the cube with the purified water, the aperture was filled with the same fluid; the crucible was positively electrified by a strong Voltaic power, and a negatively electrified wire introduced into the aperture.

The water soon gained the property of affecting the tint of turmeric; and fixed alkali and lime were both obtained from it; and this effect took place in repeated experiments; the fixed alkali, however, diminished in quantity every time; and after eleven processes conducted from two to three hours each, disappeared altogether. The production of lime-water was uniform.

I made a solution of 500 grains of this marble in nitric acid; I decomposed the mixture by carbonate of ammonia, and I collected and evaporated the fluid part, and decomposed the nitrate of ammonia by heat. About $\frac{3}{4}$ of a grain of fixed saline matter remained, which had soda for its base.

It was possible that the Carrara marble might have been recently exposed to sea-water; I therefore tried, in the same way, a piece of granular marble, which

I had myself broken from a rock on one of the highest of the primitive mountains of Donegal. It afforded fixed alkali by the agency of negative electricity.

A piece of argillaceous schist from Cornwall, treated in the same manner, gave the same result; and serpentine from the Lizard, and grauwacké from North Wales, both afforded soda. It is probable that there are few stones that do not contain some minute portions of saline matter, which in many cases may be mechanically diffused through their substance: and it is not difficult to conceive the possibility of this, when we consider that all our common rocks and strata bear evident marks of having been anciently covered by the sea.

I was now able to determine distinctly, that the soda procured in glass tubes came principally from the glass, as I had always supposed.

I used the two cones of gold with the purified water and the amianthus; the process was conducted as usual. After a quarter of an hour, the negatively electrified tube did not change the colour of turmeric. I introduced into the top of it a bit of glass; in a few minutes the fluid at the surface rendered the tint of the paper of a deep bright brown.

I had never made any experiments, in which acid matter having the properties of nitrous acid was not produced, and the longer the operation the greater was the quantity that appeared.

Volatile alkali likewise seemed to be always formed in very minute portions, during the first few minutes in the purified water in the gold cones, but the limit to its quantity was soon attained.

It was natural to account for both these appearances, from the combination of nascent oxygen and hydrogen respectively with the nitrogen of the common air dissolved in water: and Dr. Priestley's experiments on the absorption of gases by water (on this idea) would furnish an easy explanation of the causes of the constant production of the acid, and the limited production of the alkali: for hydrogen, during its solution in water, seems to expel nitrogen; whilst nitrogen and oxygen are capable of co-existing dissolved in that fluid.*

To render the investigation more complete, I introduced the two cones of gold with purified water under the receiver of an air-pump; the receiver was exhausted till it contained only 1-64th of the original quantity of air; and then, by means of a convenient apparatus, the tubes were connected with an active Voltaic pile of fifty pairs of plates of four inches square. The process was carried on for eighteen hours, when the result was examined. The water in the negative tube produced no effect upon prepared litmus, but that in the positive tube gave it a barely perceptible tinge of red.

An incomparably greater quantity of acid would have been formed in a similar time in the atmosphere, and the small portion of nitrogen gas remaining in contact with the water, seemed adequate to the effect.

I repeated the experiment under more conclusive circumstances. I arranged the apparatus as before; I exhausted the receiver, and filled it with hydrogen gas from a convenient air-holder; I made a second exhaustion, and again introduced hydrogen that had been carefully prepared. The process was conducted for twenty-four hours, and at the end of this time neither of the portions of the water altered in the slightest degree the tint of litmus.

It seems evident then that water, chemically pure, is decomposed by electricity into gaseous matter alone, into oxygen and hydrogen.

The cause of its decomposition, and of the other decompositions which have been mentioned, will be hereafter discussed.

III.—ON THE AGENCIES OF ELECTRICITY IN THE DECOMPOSITION OF VARIOUS COMPOUNDS.

The experiments that have been detailed on the production of alkali from glass, and on the decomposition of various saline compounds contained in animal and vegetable substances, offered some curious objects of inquiry.

It was evident, that in all changes in which acid and alkaline matter had been present, the acid matter collected in the water round the positively electrified metallic surface; and the alkaline matter round the negatively electrified metallic

* Priestley's Experiments and Observations, vol. i. page 59.

surface; and this principle of action appeared immediately related to one of the first phenomena observed in the Voltaic pile, the decomposition of the muriate of soda attached to the paste-board; and to many facts which have been since observed on the separation of the constituent parts of neutrosaline and metallic solutions, particularly those detailed by MM. Hisinger and Berzelius.*

The first experiments that I made immediately with respect to this subject were on the decomposition of solid bodies, insoluble, or difficultly soluble in water. From the effects of the electrical agency on glass, I expected that various earthy compounds would undergo change under similar circumstances; and the results of the trials were decided and satisfactory.

Two cups made of compact sulphate of lime, containing about fourteen grain-measures of water each, were connected together by fibrous sulphate of lime, which was moistened by pure water: the cups were filled with this fluid; platina wires from the Voltaic battery of 100 pairs of plates of six inches were introduced into them, so that the circuit of electricity was through the fibrous sulphate of lime. In five minutes the water in the cup connected with the positive wire became acid; that in the opposite cup strongly tinged turmeric. After an hour the fluids were accurately examined; when it was found that a pure and saturated solution of lime had been produced in the cup containing the negative wire, which was partially covered with a crust of lime; and that the other cup was filled with a moderately strong solution of sulphuric acid.

I procured two cubical pieces of crystallized sulphate of strontites, of about an inch; a hole was drilled in each capable of containing about eight grains of water: the cubes were plunged in pure water in a platina crucible; and the level of the fluid preserved a few lines below the surface of the cubes; two platina wires were introduced into the holes, which were filled with pure water. The disengagement of gas, when the wires were connected with the battery of 100, proved that the sulphate of strontites was sufficiently porous to form a proper conducting chain. The results were much longer in being obtained in this experiment than in the last: some time elapsed before a sensible effect could be perceived; but the termination was similar. In thirty hours the fluid in the cavity containing the negative wire had gained the property of precipitating solution of sulphate of potash; and the presence of sulphuric acid in the other cavity was evident from its effect upon solution of muriate of barytes.

I made an experiment upon fluate of lime under like circumstances; but the crystallized fluate not being equally permeable to moisture, the two cavities were connected by moist asbestus. This decomposition was likewise very slow; but in the course of two days a pretty strong solution of lime was obtained in one tube; and an acid fluid in the other, which precipitated acetite of lead, and left a spot upon the glass from which it had been evaporated.

Sulphate of barytes, as might be supposed, proved much more difficult of decomposition than either sulphate of strontites or fluate of lime. I had made four or five experiments upon it, with the same kind of apparatus that had been applied to the fluate of lime, before I was able to gain decided results. In the last process performed on this substance, two pieces of a large single crystal were hollowed by grinding, so as to contain about five grains of water each; they were connected by moist asbestus, and constantly subjected during four days to the strong action of a battery of 150 pairs of plates of 4 inches square. As the water diminished, its place was supplied by new quantities. At the conclusion of the experiment the fluid on the positive side of the apparatus instantly reddened litmus, tasted very sour, and gave a distinct precipitate with a solution of muriate of barytes; the water on the other side deepened the tincture of turmeric; but did not render solution of sulphate of potash turbid. There was a small quantity of white crust, however, on the sides and bottom of the cavity, and I conceived that this might be the barytes, which, during the extremely slow decomposition, would have combined with the carbonic acid of the atmosphere. To ascertain if this had been the case, I introduced into the cavity a drop of diluted muriatic acid; a slight effervescence appeared, and the fluid obtained occasioned a distinct white cloudiness in solution of sulphate of soda.

In all these cases the constituent parts of the bodies newly arranged by the

* Annales de Chimie, tom. li. p. 167

effects of electricity existed in considerable quantities, and exposed on a large surface to its action. I had great reason to believe, however, from the trials with distilled water in different vessels, that very minute portions of acid and alkaline matter might be disengaged by this agency from solid combinations, principally consisting of the pure earths.

This part of the investigation was easily elucidated.

For a purpose of geological inquiry, which on a future occasion I shall have the honour of laying before the Society, I had made a careful analysis of a specimen of fine grained basalt from Port Rush in the county of Antrim, by means of fusion with boracic acid: it had afforded in 100 parts 3½ parts of soda, and nearly ½ a part of muriatic acid, with 15 parts of lime. This stone appeared to me very well fitted for the purpose of experiment: cavities were drilled in two pieces, properly shaped; they contained about 12 grains of water each; they were connected by moistened amianthus, and the process conducted as usual with a power of 50 pairs of plates. At the end of ten hours the result was examined with care. The fluid that had been positively electrified had the strong smell of oxy-muriatic acid, and copiously precipitated nitrate of silver; the other portion of fluid affected turmeric, and left by evaporation a substance which seemed to be a mixture of lime and soda.

A part of a specimen of compact zeolite, from the Giant's Causeway, which by analysis had given 7 parts in 100 of soda, had a small cavity made in it; it was immerged in pure water in a crucible of platina, and electrified in the same manner as the cube of Carrara marble, mentioned in page 4. In less than two minutes the water in the cavity had gained the property of changing the colour of turmeric; and in half an hour the solution was disagreeably alkaline to the taste. The matter dissolved proved to be soda and lime.

Lepidolite, treated in the same way, gave potash.

A piece of vitreous lava, from Etna, gave alkaline matter, which seemed to be a mixture of soda, potash, and lime.

As in these trials the object was merely to ascertain the general fact of decomposition, the process was never conducted for a sufficient time to develope a quantity of alkaline matter capable of being conveniently weighed, and of course any loss of weight of the substance could not be determined.

I thought it right, however, to make one experiment of this kind, for the sake of removing every possibility of doubt on the source of the different products; and I selected for this purpose glass, as a substance apparently insoluble in water, and not likely to afford in any way erroneous results.

The balance that I employed was made for the Royal Institution, by Mr. Fidler, after the model of that belonging to the Royal Society; it turns readily with 1-500 of a grain when loaded with 100 grains on each side; a glass tube with a platina wire attached, weighing 84 grains 56-128 was connected with an agate cup, by amianthus; they were filled with purified water, and electrified by a power from 150 pairs of plates, in such a way that the platina in the glass tube was negative. The process was continued for four days, when the water was found alkaline. It gave by evaporation and exposure to a heat of about 400° Fahrenheit, soda mixed with a white powder insoluble in acids, the whole weight of which 36-128 of a grain. The glass tube carefully cleaned and dried weighed 84 grains, 37-128. The difference between the loss of weight of the tube and the weight of the products in the water may be easily explained: some minute detached particles of amianthus were present, and the soda must have contained water, a substance which it is probably perfectly free from in glass.

Having obtained such results with regard to the disengagements of the saline parts of bodies insoluble in water, I made a number of experiments on soluble compounds; their decomposition was always much more rapid, and the phenomena perfectly distinct.

In these processes I employed the agate cups with platina wires, connected by amianthus moistened in pure water; the solutions were introduced into the cups, and the electrifying power applied from batteries of 50 pairs of plates, in the usual way.

A diluted solution of sulphate of potash treated in this manner, produced in four hours at the negative wire a weak lixivium of potash; and a solution of sulphuric acid at the positive wire.

The phenomena were similar when sulphate of soda, nitrate of potash, nitrate of barytes, sulphate of ammonia, phosphate of soda, succinate, oxalate, and benzoate of ammonia, and alum were used. The acids in a certain time collected in the tube containing the positive wire, and the alkalies and earths in that containing the negative wire.

Solutions of the muriatic salts, decomposed in the same way, uniformly gave oxymuriatic acid on the positive side.

When compatible mixtures of neutrosaline solutions containing the common mineral acids were used, the different acids and the different basis seemed to separate together in a mixed state, without any respect to the orders of affinity.

When metallic solutions were employed, metallic crystals or depositions were formed, as in common galvanic experiments, on the negative wire, and oxide was likewise deposited round it; and a great excess of acid was soon found in the opposite cup. With solutions of iron, zinc, and tin, this effect took place, as well as with the more oxidable metals: when muriate of iron was used, the black substance deposited upon the wire was magnetic, and dissolved with effervescence in muriatic acid; and when sulphate of zinc was used, a gray powder possessed of the metallic lustre, and likewise soluble with effervescence, appeared; and in all cases, acid in excess was exhibited on the positive side.

Strong or saturated saline solutions, as might have been expected, afforded indications of the progress of decomposition much more rapidly than weak ones; but the smallest proportion of neutrosaline matter seemed to be acted on with energy.

A very simple experiment demonstrates this last principle. If a piece of paper tinged with turmeric, is plunged into pure water in a proper circuit, in contact with the negative point, the very minute quantity of saline compound contained in the paper, affords alkaline matter sufficient to give it instantly a brown tint near its point of contact: and acid in the same manner is immediately developed from litmus paper, at the positive surface.

I made several experiments, with the view of ascertaining whether, in the decompositions by electricity, the separation of the constituent parts was complete from the last portions of the compound; and whenever the results were distinct, this evidently appeared to be the case.

I shall describe one of the most conclusive of the experiments: a very weak solution of sulphate of potash, containing 20 parts water and one part saturated solution, at 64°, was electrified in the two agate cups by the power of 50 pairs of plates for three days: the connecting amianthus, which had been moistened with pure water, was removed, washed with pure water, and again applied, twice every day; by this precaution the presence of any neutral salt that might adhere to it, and disturb the results was prevented. The alkali obtained in this process in the solution had the properties of pure potash; and when it had been saturated with nitric acid it gave no turbidness by mixture with solution of muriate of barytes: the acid matter exposed to a strong heat evaporated without leaving any residuum.

IV.—ON THE TRANSFER OF CERTAIN OF THE CONSTITUENT PARTS OF BODIES BY THE ACTION OF ELECTRICITY.

M. Gautherot has stated,* that in a single galvanic circle of zinc, silver, and water, in an active state, the oxide of zinc formed is attracted by the silver;† and MM. Hisinger and Berzelius detail an account of an experiment, in which solution of muriate of lime being placed in the positive part of a siphon, electrified by wires from a Voltaic pile, and distilled water in the negative part, lime appeared in the distilled water.

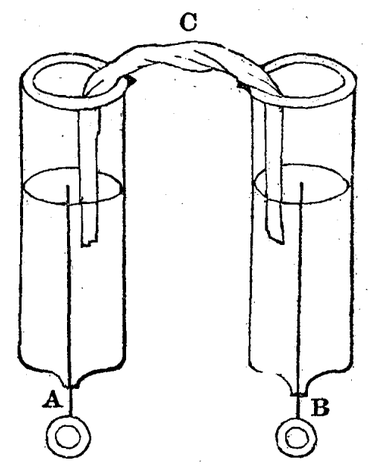
These facts rendered it probable, that the saline elements evolved in decompositions by electricity were capable of being transferred from one electrified surface to another, according to their usual order of arrangement: but to demonstrate this clearly, new researches were wanting.

I connected one of the cups of sulphate of lime, mentioned page 6, with a cup of agate by asbestus; and, filling them with purified water, made the platina wire

* Annales de Chimie, vol. xxxix. page 203. † Ibid. vol. li. page 171.

in the cup of sulphate of lime transmit the electricity from a power of 100; a wire in the agate cup received it. In about four hours a strong solution of lime was found in the agate cup, and sulphuric acid in the cup of sulphate of lime. By reversing the order, and carrying on the process for a similar time, the sulphuric acid appeared in the agate cup, and the solution of lime on the opposite side.

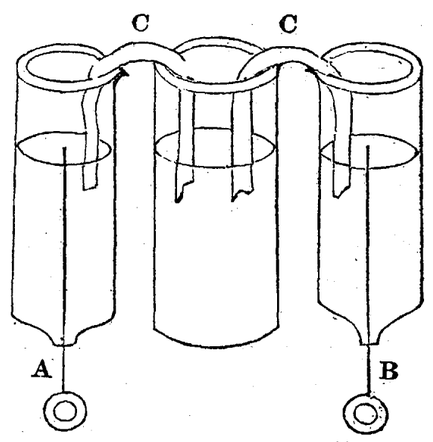
Many trials were made with other saline substances, with analogous results. When the compounds of the strong mineral acids with alkaline or alkaline-earthy bases, were introduced into one tube of glass, distilled water connected by amianthus being in another tube, both connected by wires of platina in the Voltaic arrangement, the base always passed into the distilled water when it was negative, and the acid when it was positive.



The metals and the metallic oxides passed towards the negative surface like the alkalies, and collected round it. In a case in which solution of nitrate of silver was used on the positive side, and distilled water on the negative, silver appeared on the whole of the transmitting amianthus, so as to cover it with a thin metallic film.

The time required for these transmissions (the quantity and intensity of the electricity, and other circumstances remaining the same) seemed to be in some proportion as the length of the intermediate volume of water. Thus when with the power of 100, sulphate of potash was on the negative side, and distilled water on the positive side, the distance between the wires being only an inch, sulphuric acid, in sufficient quantity to be very manifest, was found in the water in less than five minutes; but when the tubes were connected by an intermediate vessel of pure water, so as to make the circuit eight inches, fourteen hours were required to produce the same effect.

To ascertain whether the contact of the saline solution with a metallic surface was necessary for the decomposition and transfer, I introduced purified water into two glass tubes; a vessel containing solution of muriate of potash was connected with them respectively by amianthus; and the arrangement was made in such a way, that the level of both the portions of purified water was higher than the level of the saline solution.



In this case, the saline matter was distant from each of the wires at least two-thirds of an inch; yet alkaline matter soon appeared in one tube, and acid matter in the other: and in sixteeen hours moderately strong solutions of potash, and of muriatic acid, had been formed.

In this case of electrical transfer or attraction, the acid and alkaline matter seemed to be perfectly pure; and I am inclined to believe that this is uniformly the case in all experiments carefully made. One of the instances in which I conceived acid most likely to be present was in the transfer of magnesia from sulphate of magnesia in the positive tube, to distilled water in the negative tube. I examined the case, taking care that the distilled water was never upon a lower level than the saline solution: the process was continued for some hours, till a considerable quantity of magnesia had appeared. The connecting amianthus was removed, and muriatic acid poured into the tube: the saturated solution did not precipitate solution of muriate of barytes.

I endeavoured to ascertain the progress of the transfer, and the course of the acid or alkaline matter in these decompositions, by using solutions of litmus and turmeric, and papers coloured by these substances: and these trials led to the knowledge of some singular and unexpected circumstances.

Two tubes, one containing distilled water, the other solution of sulphate of potash, were each connected by amianthus with a small ounce measure filled with distilled water tinged by litmus: the saline solution was negatively electrified; and as it was natural to suppose, that the sulphuric acid in passing through the

water to the positive side would redden the litmus in its course, some slips of moistened paper tinged with litmus were placed above and below the pieces of amianthus, directly in the circuit. The progress of the experiment was minutely observed; the first effect of reddening took place immediately above the positive surface, where I had least expected it; the red tint slowly diffused itself from the positive side to the middle of the vessel, but no redness appeared above the amianthus, or about it, on the negative side; and, though it had been constantly transmitting sulphuric acid, it remained unaffected to the last.

The order of the experiment was changed, and the saline solution placed on the positive side; a solution and papers tinged with turmeric being substituted for those tinged with litmus. The effect was precisely analogous; the turmeric became brown first, near the negative wire, and no change took place in the intermediate vessel near the positive wire.

In another process, the two glass tubes were filled with solution of muriate of soda, and the intermediate vessel with solution of sulphate of silver; paper tinged with turmeric was placed on the positive side, and paper tinged with litmus on the negative side; as soon as the electrical circuit was complete, soda began to appear in the negative tube, and oxymuriatic acid in the positive tube; and the alternate products were exhibited passing into the solution of sulphate of silver, the muriatic acid occasioning a dense heavy precipitate, and the soda a more diffused and a lighter one; but neither the turmeric transmitting the alkali, nor the litmus transmitting the acid, had their tints in the slightest degree altered.

V.—ON THE PASSAGE OF ACIDS, ALKALIES, AND OTHER SUBSTANCES, THROUGH VARIOUS ATTRACTING CHEMICAL MENSTRUA, BY MEANS OF ELECTRICITY.

As acid and alkaline substances, during the time of their electrical transfer, passed through water containing vegetable colours without affecting them, or apparently combining with them, it immediately became an object of inquiry, whether they would not likewise pass through chemical menstrua, having stronger attractions for them; and it seemed reasonable to suppose, that the same power which destroyed elective affinity in the vicinity of the metallic points, would likewise destroy it, or suspend its operation, throughout the whole of the circuit.

An arrangement was made, of the same vessels and apparatus employed in the experiment on the solution of muriate of soda and sulphate of silver, as above. Solution of sulphate of potash was placed in contact with the negatively electrified point, pure water was placed in contact with the positively electrified point, and a weak solution of ammonia was made the middle link of the conducting chain; so that no sulphuric acid could pass to the positive point in the distilled water, without passing through the solution of ammonia.

The power of 150 was used: in less than five minutes it was found, by means of litmus paper, that acid was collecting round the positive point; in half an hour, the result was sufficiently distinct for accurate examination.

The water was sour to the taste, and precipitated solution of nitrate of barytes.

Similar experiments were made with solution of lime; and weak solutions of potash and soda, and the results were analogous. With strong solutions of potash and soda a much longer time was required for the exhibition of the acid; but even with the most saturated alkaline lixivium, it always appeared in a certain period.

Muriatic acid, from muriate of soda, and nitric acid, from nitrate of potash, were transmitted through concentrated alkaline menstrua, under similar circumstances.

When distilled water was placed in the negative part of the circuit, and a solution of sulphuric, muriatic, or nitric acid, in the middle, and any neutral salt with a base of lime, soda, potash, ammonia, or magnesia, in the positive part, the alkaline matter was transmitted through the acid matter to the negative surface, with similar circumstances to those occurring during the passage of the acid through the alkaline menstrua; and the less concentrated the solution, the greater seemed to be the facility of transmission.

I tried in this way muriate of lime with sulphuric acid, nitrate of potash with muriatic acid, sulphate of soda with muriatic acid, and muriate of magnesia with sulphuric acid; I employed the power of 150; and in less than 48 hours, I gained in all these cases decided results; and magnesia came over like the rest.

Strontites and barytes passed, like the other alkaline substances, readily through muriatic and nitric acids; and, *vice versa*, these acids passed with facility through aqueous solutions of barytes and strontites; but in experiments in which it was attempted to pass sulphuric acid through the *same menstrua*, or to pass barytes or strontites through this acid, the results were very different.

When solution of sulphate of potash was in the negative part of the circuit, distilled water in the positive part, and saturated solution of barytes in the middle, no sensible quantity of sulphuric acid existed in the distilled water after 30 hours, the power of 150 being used; after four days, sulphuric acid appeared, but the quantity was extremely minute; much sulphate of barytes had formed in the intermediate vessel; the solution of barytes was so weak as barely to tinge litmus; and a thick film of carbonate of barytes had formed on the surface of the fluid. With solution of strontites the result was very analogous, but the sulphuric acid was sensible in three days.

When solution of muriate of barytes was made positive by the power of 150, concentrated sulphuric acid intermediate, and distilled water negative, no barytes appeared in the distilled water, when the experiment had been carried on for four days; but much oxymuriatic acid had formed in the positive vessel, and much sulphate of barytes had been deposited in the sulphuric acid.

Such of the metallic oxides as were made subjects of experiment passed through acid solutions from the positive to the negative side, but the effect was much longer in taking place than in the instances of the transition of alkaline matter. When solution of green sulphate of iron was made positive, solution of muriatic acid intermediate, and water negative, in the usual arrangement, green oxide of iron began to appear in about ten hours upon the negative connecting amianthus, and in three days a considerable portion had been deposited in the tube. Analogous results were obtained with sulphate of copper, nitrate of lead, and nitromuriate of tin.

I made several experiments on the transition of alkaline and acid matter through different neutrosaline solutions, and the results were such as might well have been anticipated.

When solution of muriate of barytes was negative, solution of sulphate of potash intermediate, and pure water positive, the power being from 150, sulphuric acid appeared in about five minutes in the distilled water; and in two hours the muriatic acid was likewise very evident. When solution of sulphate of potash was positive, solution of muriate of barytes intermediate, and distilled water negative, the barytes appeared in the water in a few minutes; the potash from the more remote part of the chain was nearly an hour in accumulating, so as to be sensible.

When the solution of muriate of barytes was positive, the solution of sulphate of potash intermediate, and distilled water negative, the potash soon appeared in the distilled water; a copious precipitation of sulphate of barytes formed in the middle vessel; but after ten hours no barytes had passed into the water.

When solution of sulphate of silver was interposed between solution of muriate of barytes on the negative side, and pure water on the positive side, sulphuric acid alone passed into the distilled water; and there was a copious precipitation in the solution of sulphate of silver. This process was carried on for ten hours.

I tried several of these experiments of transition upon vegetable and animal substances with perfect success.

The saline matter exposed in contact with the metal, and that existing in the vegetable or animal substances, both underwent decomposition and transfer; and the time of the appearance of the different products at the extremities of the circuit was governed by the degree of their vicinity.

Thus, when a fresh leaf-stalk of the polyanthus, about two inches long, was made to connect a positively electrified tube containing solution of nitrate of strontites, and a negatively electrified tube containing pure water, the water soon became green, and gave indications of alkaline properties, and free nitric acid was rapidly separated in the positive tube. After ten minutes, the alkaline matter was examined; it consisted of potash and lime, and as yet no strontites had been carried into it; for the precipitate it gave with sulphuric acid readily dissolved in muriatic acid. In half an hour strontites, however, appeared; and in four hours it formed a very abundant ingredient of the solution.

A piece of muscular flesh of beef, of about three inches in length and half an inch in thickness, was treated in the same way as the medium of communication between muriate of barytes and distilled water. The first products were soda, ammonia, and lime; and after an hour and a quarter, the barytes was very evident. There was much free oxymuriatic acid in the positively electrified tube, but no particle of muriatic acid had passed into the negative tube, either from the muriatic solution or from the muscular fibre.

VI.—SOME GENERAL OBSERVATIONS ON THESE PHENOMENA, AND ON THE MODE OF DECOMPOSITION AND TRANSITION.

It will be a general expression of the facts that have been detailed, relating to the changes and transitions by electricity, in common philosophical language, to say, that hydrogen, the alkaline substances, the metals, and certain metallic oxides, are attracted by negatively electrified metallic surfaces, and repelled by positively electrified metallic surfaces: and contrarywise, that oxygen and acid substances are attracted by positively electrified metallic surfaces, and repelled by negatively electrified metallic surfaces; and these attractive and repulsive forces are sufficiently energetic to destroy or suspend the usual operation of elective affinity.

It is very natural to suppose, that the repellent and attractive energies are communicated from one *particle to another particle* of the same kind, so as to establish a conducting chain in the fluid; and that the locomotion takes place in consequence: and that this is really the case seems to be shown by many facts. Thus, in all the instances in which I examined alkaline solutions through which acids had been transmitted, I always found acid in them whenever any acid matter remained at the original source. In time, by the attractive power of the positive surface, the decomposition and transfer undoubtedly become complete; but this does not affect the conclusion.

In the cases of the separation of the constituents of water, and of solutions of neutral salts forming the whole of the chain, there may possibly be a succession of decompositions and recompositions throughout the fluid. And this idea is strengthened by the experiments on the attempt to pass barytes through sulphuric acid, and muriatic acid through solution of sulphate of silver, in which, as insoluble compounds are formed and carried out of the sphere of the electrical action, the power of transfer is destroyed. A similar conclusion might likewise be drawn from many other instances. Magnesia and the metallic oxides, as I have already mentioned, will pass along moist amianthus from the positive to the negative surface; but if a vessel of pure water be interposed, they do not reach the negative vessel, but sink to the bottom. These experiments I have very often made, and the results are perfectly conclusive; and in the case, page 11, in which sulphuric acid seemed to pass in small quantities through very weak solutions of strontites and barytes, I have no doubt but that it was carried through by means of a thin stratum of pure water, where the solution had been decomposed at the surface by carbonic acid; for in an experiment similar to these in which the film of carbonate of barytes was often removed and the fluid agitated, no particle of sulphuric acid appeared in the positive part of the chain.

It is easy to explain, from the general phenomena of decomposition and transfer, the mode in which *oxygen* and *hydrogen* are separately evolved from water. The oxygen of a portion of water is attracted by the positive surface, at the same time that the other constituent part, the hydrogen is repelled by it; and the opposite process takes place at the negative surface; and in the middle or neutral point of the circuit, whether there be a series of decompositions and recompositions, or whether the particles from the extreme points only are active, there must be a new combination of the repelled matter; and the case is analogous to that of two portions of muriate of soda separated by distilled water; muriatic acid is repelled from the negative side, and soda from the positive side, and muriate of soda is composed in the middle vessel.

These facts seem fully to invalidate the conjectures of M. Ritter, and some other philosophers, with regard to the elementary nature of water, and perfectly to confirm the great discovery of Mr. Cavendish.

M. Ritter conceived that he had procured oxygen from water without hydro-

gen, by making sulphuric acid the medium of communication at the negative surface; but in this case, sulphur is deposited, and the oxygen from the acid, and the hydrogen from the water are respectively repelled; and the new combination produced.

I have attempted some of the experiments of decomposition and transfer, by means of common electricity, making use of a powerful electrical machine of Mr. Nairne's construction, belonging to the Royal Institution, of which the cylinder is fifteen inches in diameter, and two feet long.

With the same apparatus as that employed for decompositions by the Voltaic battery, no perceptible effect was produced by passing a strong current of electricity silently for four hours through solution of sulphate of potash.

But by employing fine platina points of one-seventieth of an inch in diameter, cemented in glass tubes in the manner contrived by Dr. Wollaston,* and bringing them near each other in vessels containing from three to four grains of the solution, and connected by moist asbestus, potash appeared in less than two hours round the negatively electrified point, and sulphuric acid round the positive point.

In a similar experiment sulphuric acid was transferred through moist asbestus into water; so that there can be no doubt that the principle of action is the same in common and the Voltaic electricity.†

VII.—ON THE GENERAL PRINCIPLES OF THE CHEMICAL CHANGES PRODUCED BY ELECTRICITY.

The experiments of Mr. Bennet had shown, that many bodies brought into contact and afterwards separated, exhibited *opposite* states of electricity; but it is to the investigations of Volta that a clear development of the fact is owing; he has distinctly shown it in the case of copper and zinc, and other metallic combinations; and has supposed that it also takes place with regard to metals and fluids.

In a series of experiments made in 1801,‡ on the construction of electrical combinations by means of alternations of single metallic plates, and different strata of fluids, I observed that when acid and alkaline solutions were employed as elements of these instruments, the alkaline solutions always received the electricity from the metal, and the acid always transmitted it to the metal; thus, in an arrangement of which the elements were tin, water, and solution of potash, the circulation of the electricity was from the water to the tin, and from the tin to the solution of potash; but in an arrangement composed of weak nitric acid, water, and tin; the order was from the acid to the tin, and from the tin to the water.

These principles seem to bear an immediate relation to the general phenomena of decomposition and transference, which have been the subject of the preceding details.

In the simplest case of electrical action, the alkali which receives electricity from the metal would necessarily, on being separated from it, appear positive; whilst the acid under similar circumstances would be negative: and these bodies having respectively with regard to the metals, that which may be called a positive and a negative electrical energy, in their repellent and attractive functions seem to be governed by

* Phil. Trans. vol. xci. p. 427.

† This had been shown, with regard to the decomposition of water, by Dr. Wollaston's important researches. By carefully avoiding sparks, I have been able to obtain the two constituents in a separate state. In an experiment in which a fine platina point cemented in glass, and connected by a single wire with the positive conductor of this machine, was plunged in distilled water in an insulated state, and the electricity dissipated into the atmosphere by means of moistened filaments of cotton, oxygen gas, mixed with a little nitrogen gas, was produced; and, when the same apparatus was applied to the negative conductor, hydrogen gas was evolved, and a minute portion of oxygen and nitrogen gases; but neither of the foreign products, the nitrogen gas in the one case and the nitrogen and oxygen gases in the other, formed as much as one thirtieth part of the volume of the gases; and there is every reason to suppose that they were derived from the extrication of common air, which had been dissolved in the water. This result, which when I first obtained it in 1803, appeared very obscure, is now easily explained; the alternate products must have been evolved at the points of the dissipation of the electricity.

‡ See Phil. Trans. vol. xci. p. 397.

laws the same as the common laws of electrical attraction and repulsion. The body possessing the positive energy being repelled by positively electrified surfaces, and attracted by negatively electrical surfaces; and the body possessing the negative energy following the contrary order.

I have made a number of experiments with the view of elucidating this idea, and of extending its application; and, in all cases, they have tended to confirm the analogy in a remarkable manner.

Well burned charcoal, water and nitric acid, the same substance, water and solution of soda, made respectively elements of different electrical combinations, became distinctly active when 20 alternations were put together: the positive energy being exhibited on the side of the alkali, and the negative on that of the acid. Arrangements of plates of zinc, pieces of moistened pasteboard, and moistened quick lime, to the number of 40 series, likewise formed a weak electrical pile, the effect of the lime being similar to that of an alkali, but the power was soon lost.

I endeavoured, by means of very delicate instruments, to ascertain the electrical states of single insulated acid and alkaline solutions, after their contact with metals; and for this purpose I employed at different times the condensing electrometer of Mr. Cuthbertson's construction, Mr. Cavallo's multiplier, and a very sensible electrical balance, on the principle of torsion, adopted by M. Coulomb; but the effects were unsatisfactory, the circumstances of evaporation, and of chemical action, and the adherence of the solutions to the surfaces of the metals employed, in most cases prevented any distinct result, or rendered the source of the electricity doubtful. I shall not enter into any details of these processes, or attempt to draw conclusions from capricious and uncertain appearances, which, as we shall immediately see, may be fully deduced from clear and distinct ones.

The alkaline and acid substances capable of existing in the dry and solid form, give by contact with the metals exceedingly sensible electricities, which require for their exhibition the gold leaf electrometer only with the small condensing plate.

When oxalic, succinic, benzoic, or boracic acid, perfectly dry, either in powder or crystals, were touched upon an extended surface with a plate of copper insulated by a glass handle, the copper was found positive, the acid negative. In favourable weather, and, when the electrometer was in perfect condition, one contact of the metal was sufficient to produce a sensible charge; but seldom more than five or six were required. Other metals, zinc and tin for instance, were tried with the same effect. And the metal received the positive charge, apparently to the same extent, whether the acid was insulated upon glass, or connected with the ground.

The solid acid of phosphorus, which had been strongly ignited, and most carefully excluded from the contact of air, rendered the insulated plate of zinc positive by four contacts; but after exposure to the atmosphere for a few minutes it wholly lost this power.

When metallic plates were made to touch dry lime, strontites, or magnesia, the metal became negative; the effect was exceedingly distinct, a single contact upon a large surface being sufficient to communicate a considerable charge. For these experiments the earths were carefully prepared; they were in powder, and had been kept for several days in glass bottles before they were used; it is essential to the success of the process that they be of the temperature of the atmosphere. In some experiments which I made upon them when cooling, after having been ignited, they appeared strongly electrical, and rendered the conductors brought in contact with them positive.

I made several experiments in a similar manner on the effects of the contact of potash and soda with the metals. Potash in no instance afforded a satisfactory result; its powerful attraction for water presents an obstacle probably unsurmountable to the success of any trials made in the free atmosphere. Soda, in the only case in which electricity was exhibited, affected the metal in the same way as lime, strontites, and magnesia. Upon this occasion, the soda had been prepared with great care, exposed in a platina crucible for nearly an hour in a red heat, and suffered to cool in the crucible inverted over mercury; when cool it was immediately removed, and the contract made with a plate of zinc; the experiment was performed in the open air; the weather was peculiarly dry, the thermometer

stood at 28° Fahrenheit, and the barometer at 30·2 inches; six contacts gave a charge to the condensing electrometer in the first trial; in the second ten were required to produce a similar effect: and after this, though two minutes only had elapsed, no farther result could be obtained.

In the decomposition of sulphuric acid by Voltaic electricity, the sulphur separates on the negative side. The experiments of various electricians prove, that by the friction of sulphur and metals, the sulphur becomes positive and the metals negative; the same thing I find happens from the contact of an unexcited cake of sulphur and insulated metallic plates. Mr. Wilke has stated an exception to lead, as rendering sulphur negative by its friction. The results that I have obtained with lead, in trials very carefully made, are the same as those with other metals.* Sulphur, by being rubbed or struck against newly-polished lead, always became positive. Mr. Wilke perhaps was misled by using tarnished lead: sulphur, I find, rubbed against litharge, or lead the surface of which has been long exposed to air, becomes negative; and, this exception being removed, all the facts on the subject are confirmations of the general principle.†

On the general principle, oxygen and hydrogen ought to possess, with regard to the metals respectively, the negative and positive energy. This I have not been able to prove by direct experiments of contact; but the idea is confirmed by the agency of their compounds; thus I have found that solution of sulphuretted hydrogen in water acts in the electrical apparatus composed of single plates and different strata of fluids, in the same manner as alkaline solutions; and that solution of oxymuriatic acid is more powerful in similar arrangements than solutions of muriatic acid of a higher degree of concentration; and, in both these cases, it is impossible to conceive the combined hydrogen and oxygen inactive. The inference, likewise, is fully warranted by the case of the solutions of alkaline hydroguretted sulphurets, which, consisting principally of alkali and sulphur together in union with water, exhibit the positive energy with regard to the metals in a very high degree. In the series of experiments on Voltaic arrangements constructed with single plates above-mentioned, I found the solutions of hydroguretted sulphurets in general much more active than alkaline solutions, and particularly active with copper, silver, and lead. And in an experiment that I made on a combination of copper, iron, and hydroguretted sulphurets of potash, in 1802, I found that the positive energy of the hydroguretted sulphurets with regard to the copper was sufficient to overpower that of the iron; so that the electricity did not circulate from the copper to the iron, and from the iron to the fluid, as in common cases, but from the copper to the hydroguretted sulphuret, and from the hydroguretted sulphuret to the iron.

All these details afford the strongest confirmation of the principle. It may be considered almost as a mere arrangement of facts; and with some extensions it seems capable of being generally applied.

Bodies possessing opposite electrical energies with regard to one and the same body, we might fairly conclude would likewise possess them with regard to each other. This, I have found by experiment, is the case with lime and oxalic acid. A dry piece of lime, made from a very pure compact secondary limestone, and of such a form as to present a large smooth surface, became positively electrical by repeated contacts with crystals of oxalic acid; and these crystals placed upon the

* As sulphur is a nonconductor, and easily excited by slight friction, or small changes in its temperature, some caution is required in drawing conclusions from the experiments in which it is employed. Sulphur, examined immediately after having been heated, gives a positive charge to conductors, agreeing in this respect with the alkaline substances; and a slight contact with the dry hand is sufficient to render it negative. In general, likewise, in experiments of contact, care should be taken that the metallic plate is free from electricity: well polished plates of copper and zinc will, I find, receive a negative charge from being laid on a table of common mahogany.

† Concentrated solution of phosphoric acid, I find, is decomposed by Voltaic electricity; the phosphorus combines with the negatively electrified metal, and forms a phosphuret; at least this happened in the two cases that I tried with platina and copper. From all analogy it may be inferred, that the electrical energy of this inflammable substance with regard to metals is the same as that of sulphur. I tried some experiments of contact upon it, but without success. Its slow combustion in the atmosphere, it is most likely, was the cause of the failure; but, even in gases not containing free or loosely combined oxygen, its evaporation would probably interfere.

top of a condensing electrometer, and repeatedly touched by the lime, which after each contact was freed from its charge, rendered the gold leaves negatively electrical. The tendency of the mere contacts of the acid and alkali with the metal would be to produce opposite effec's to those exhibited, so that their mutual agency must have been very energetic.

It will not certainly be a remote analogy to consider the other acid and alkaline substances generally, and oxygen and hydrogen as possessing similar electrical relations; and, in the decompositions and changes presented by the effects of electricity, the different bodies naturally possessed of chemical affinities appear incapable of combining, or of remaining in combination, when placed in a state of electricity different from their natural order. Thus, as we have seen, the acids in the positive part of the circuit separate themselves from alkalies, oxygen from hydrogen, and so on; and metals on the negative side do not unite to oxygen, and acids do not remain in union with their oxides; and in this way the attractive and repellent agencies seem to be communicated from the metallic surface throughout the whole of the menstruum.

VIII.—ON THE RELATIONS BETWEEN THE ELECTRICAL ENERGIES OF BODIES, AND THEIR CHEMICAL AFFINITIES.

As the chemical attraction between two bodies seems to be destroyed by giving one of them an electrical state different from that which it naturally possesses—that is, by bringing it artificially into a state similar to the other, so it may be increased by exalting its natural energy. Thus, whilst zinc, one of the most oxidable of the metals, is incapable of combining with oxygen when negatively electrified in the circuit, even by a feeble power; silver, one of the least oxidable, easily unites to it when positively electrified; and the same thing might be said of other metals.

Amongst the substances that combine chemically, all those, the electrical energies of which are well known, exhibit opposite states; thus, copper and zinc, gold and quicksilver, sulphur and the metals, the acid and alkaline substances, afford apposite instances; and, supposing perfect freedom of motion in their particles or elementary matter, they ought, according to the principles laid down, to attract each other in consequence of their electrical powers. In the present state of our knowledge, it would be useless to attempt to speculate on the remote cause of the electrical energy, or the reason why different bodies, after being brought into contact, should be found differently electrified; its relation to chemical affinity is, however, sufficiently evident. May it not be identical with it, and an essential property of matter?

The coated glass plates of Beccaria strongly adhere to each other when oppositely charged, and retain their charges on being separated. This fact affords a distinct analogy to the subject; different particles, in combining, must still be supposed to preserve their peculiar states of energy.

In the present early stage of the investigation, it would be improper to place unbounded confidence in this hypothesis; but it seems naturally to arise from the facts, and to coincide with the laws of affinity, so ably developed by modern chemists; and the general application of it may be easily made.

Supposing two bodies, the particles of which are in different electrical states, and those states sufficiently exalted to give them an attractive force superior to the power of aggregation, a combination would take place which would be more or less intense according as the energies were more or less perfectly balanced; and the change of properties would be correspondently proportional.

This would be the simplest case of chemical union. But different substances have different degrees of the same electrical energy in relation to the same body; thus the different acids and alkalies are possessed of different energies with regard to the same metal; sulphuric acid, for instance, is more powerful with lead than muriatic acid, and solution of potash is more active with tin than solution of soda. Such bodies likewise may be in the same state, or repellent with regard to each other, as apparently happens in the cases just mentioned; or they may be neutral; or they may be in opposite or attracting states, which last seems to be the condition of sulphur and alkalies that have the same kind of energy with regard to metals.

When two bodies repellent of each other act upon the same body with different degrees of the same electrical attracting energy, the combination would be determined by the degree; and the substance possessing the weakest energy would be repelled; and this principle would afford an expression of the causes of elective affinity, and the decompositions produced in consequence.

Or where the bodies having different degrees of the same energy, with regard to the third body, had likewise different energies with regard to each other, there might be such a balance of attractive and repellent powers as to produce a triple compound; and by the extension of this reasoning, complicated chemical union may be easily explained.

Numerical illustrations of these notions might be made without difficulty, and they might be applied to all cases of chemical action; but in the present state of the inquiry, a great extension of this hypothetical part of the subject would be premature.

The general idea will, however, afford an easy explanation of the influence of affinity by the masses of the acting substances, as elucidated by the experiments of M. Berthollet; for the combined effect of many particles possessing a feeble electrical energy, may be conceived equal, or even superior to the effect of a few particles possessing a strong electrical energy: and the facts mentioned, page 11, confirm the supposition: for concentrated alkaline lixivia resist the transmission of acids by electricity much more powerfully than weak ones.

Allowing combination to depend upon the balance of the natural energies of bodies, it is easy to conceive that a *measure* may be found of the artificial energies, as to intensity and quantity produced in the common electrical machine, or the Voltaic apparatus, capable of destroying this equilibrium; and such a measure would enable us to make a scale of electrical powers corresponding to degrees of affinity.

In the circuit of the Voltaic apparatus, completed by metallic wires and water, the strength of the opposite electricities diminish from the points of contact of the wires towards the middle point in the water, which is necessarily neutral. In a body of water of considerable length, it probably would not be difficult to assign the places in which the different neutral compounds yielded to, or resisted decomposition. Sulphate of barytes, in all cases that I tried, required immediate contact with the wire: solution of sulphate of potash exhibited no marks of decomposition with the power of 150, when connected in a circuit of water ten inches in length, at four inches from the positive point; but, when placed within two inches, its alkali was slowly repelled and its acid attracted.*

Whenever bodies brought by artificial means into a high state of opposite electricities are made to restore the equilibrium, heat and light are the common consequences. It is perhaps an additional circumstance, in favour of the theory to state, that heat and light are likewise the result of all intense chemical action. And as in certain forms of the Voltaic battery, where large quantities of electricity of low intensity act, heat is produced without light; so in slow combinations there is an increase of temperature without luminous appearance.

The *effect* of HEAT, in producing combination, may be easily explained according to these ideas. It not only often gives more freedom of motion to the particles, but in a number of cases it seems to exalt the electrical energies of bodies; glass, the tourmalin, sulphur, all afford familiar instances of this last species of energy.

I heated together an insulated plate of copper and a plate of sulphur, and examined their electricities as their temperature became elevated: these electricities, scarcely sensible at 56° Fahrenheit to the condensing electrometer, became at 100° Fahrenheit capable of affecting the gold leaves without condensation: they

* In this experiment, the water was contained in a circular glass bason two inches deep, the communication was made by pieces of amianthus of about the eighth of an inch in breadth. The saline solution filled a half ounce measure, and the distance between the solution and the water, at both points of communication, was a quarter of an inch. I mention these circumstances because the quantity of fluid and the extent of surface materially influence the result in trials of this kind. Water included in glass siphons forms a much less perfect conducting chain than when diffused upon the surface of fibrous nonconducting substances of much smaller volume than the diameter of the siphons. I attempted to employ siphons in some of my first experiments; but the very great inferiority of effect as compared with that of amianthus made me altogether relinquish the use of them.

increased in a still higher ratio as the sulphur approached towards its poi fusion. At a little above this point, as is well known from the experimen the Dutch chemists, the two substances rapidly combine, and heat and ligh evident.

Similar effects may be conceived to occur in the case of oxygen and hydr which form water, a body apparently neutral in electrical energy to most substances; and we may reasonably conclude that there is the same exaltati power, in all cases of combustion In general, when the different energie strong and in perfect equilibrium, the combination ought to be quick, the and light intense, and the new compound in a neutral state This would see be the case in the instance just quoted; and in the circumstances of the uni the strong alkalies and acids But where one energy is feeble and the strong, all the effects must be less vivid; and the compound, instead of being tral, ought to exhibit the excess of the stronger energy.

This last idea is confirmed by all the experiments which I have been ab make on the energies of the saline compounds with regard to the metals. Ni and sulphate of potash, muriate of lime, oxymuriate of potash, though repea touched upon a large surface by plates of copper and zinc, gave no elect charge to them; subcarbonate of soda and borax, on the contrary, gave a s negative charge, and alum and superphosphate of lime a feeble positive charg

Should this principle on further inquiry be found to apply generally, the de of the electrical energies of bodies, ascertained by means of sensible instrum will afford new and useful indications of their composition.

IX —ON THE MODE OF ACTION ON THE PILE OF VOLTA, WITH EXPERIMENT ELUCIDATIONS

The great tendency of the attraction of the different chemical agents, b positive and negative surfaces in the Voltaic apparatus, seems to be to restor electrical equilibrium. In a Voltaic battery, composed of copper, zinc, and tion of muriate of soda, all circulation of the electricity ceases, the equilibriu restored if copper be brought in contact with the zinc on both sides; and ox and acids, which are attracted by the positively electrified zinc, exert sin agencies to the copper, but probably in a slighter degree, and, being capab combination with the metal, they produce a momentary equilibrium only.

The electrical energies of the metals with regard to each other, or the stances dissolved in the water, in the Voltaic and other analogous instrum seem to be the causes that disturb the equilibrium, and the chemical change causes that tend to restore the equilibrium; and the phenomena most prob depend on their joint agency

In the Voltaic pile of zinc, copper, and solution of muriate of soda, in wha been called its condition of electrical tension, the communicating plates of co and zinc are in opposite electrical states And with regard to electricities of very low intensity, water is an insulating body: every copper plate consequ produces by induction an increase of positive electricity upon the opposite plate; and every zinc plate an increase of negative electricity on the opposite per plate: and the intensity increases with the number, and the quantity wit extent of the series

When a communication is made between the two extreme points, the opp electricities tend to annihilate each other; and if the fluid medium could be a stance incapable of decomposition, the equilibrium, there is every reason to be would be restored, and the motion of the electricity cease But solution of riate of soda being composed of two series of elements possessing opposite el cal energies, the oxygen and the acid are attracted by the zinc, and the hydr and the alkali by the copper The balance of power is momentary only solution of zinc is formed, and the hydrogen disengaged The negative ener the copper and the positive energy of the zinc are consequently again exe enfeebled only by the opposing energy of the soda in contact with the copper the process of electromotion continues as long as the chemical changes are ca of being carried on

This theory in some measure reconciles the hypothetical principles of the a of the pile adopted by its illustrious inventor, with the opinions concernin

chemical origin of Galvanism, supported by the greater number of the British philosophers, and it is confirmed and strengthened by many facts and experiments

Thus the Voltaic pile of 20 pairs of plates of copper and zinc exhibits no permanent electromotive power when the connecting fluid is water free from air;* for this substance does not readily undergo chemical change, and the equilibrium seems to be capable of being permanently restored through it. Concentrated sulphuric acid, which is a much more perfect conductor, is equally inefficient, for it has little action upon zinc, and is itself decomposed only by a very strong power. Piles, containing as their fluid element either pure water or sulphuric acid, will undoubtedly give single shocks, and this effect is connected with the restoration of the equilibrium disturbed by the energies of the metals; but when their extreme plates are connected there is no exhibition, as in usual cases of electromotion Water containing loosely combined oxygen is more efficient than water containing common air, as it enables oxide of zinc to be formed more rapidly, and in larger quantities Neutrosaline solutions, which are at first very active, lose their energy in proportion as their acid arranges itself on the side of the zinc, and their alkali on that of the copper; and I have found the powers of a combination nearly destroyed from this cause very much revived, merely by agitating the fluids in the cells and mixing their parts together Diluted acids, which are themselves easily decomposed, or which assist the decomposition of water, are above all other substances powerful; for they dissolve the zinc, and furnish only a gaseous product to the negative surface, which is immediately disengaged

There are other experiments connected with very striking results, which offer additional reasons for supposing the decomposition of the chemical menstrua essential to the continued electromotion in the pile

As when an electrical discharge is produced by means of small metallic surfaces in the Voltaic battery (the opposite state being exalted), *sensible* heat is the consequence, it occurred to me, that if the decomposition of the chemical agents was essential to the balance of the opposed electricities, the effect, in a saline solution, of this decomposition, and of the transfer of the alkali to the negative side, and of the acid to the positive side, ought, under favourable circumstances, to be connected with an increase of temperature.

I placed the gold cones, which have been so often mentioned, in the circuit of the battery with the power of 100, I filled them with distilled water, and connected them by a piece of moistened asbestus, about an inch in length and one-sixth of an inch in diameter; I provided a small air-thermometer capable of being immersed in the gold cones, expecting (if any) only a very slight change of temperature; I introduced a drop of solution of sulphate of potash into the positive cone: the decomposition instantly began: potash passed rapidly over it into the negative cone, heat was immediately sensible; and in less than two minutes the water was in a state of ebullition.

I tried the same thing with a solution of nitrate of ammonia, and in this instance the heat rose to such an intensity as to evaporate all the water in three or four minutes, with a kind of explosive noise; and at last actual inflammation took place, with the decomposition and dissipation of the greatest part of the salt †

That the increase of the conducting power of the water by the drop of saline solution had little or nothing to do with the effect, is evident from this circumstance. I introduced a quantity of strong lixivium of potash into the cones, and likewise concentrated sulphuric acid, separately, which are better conductors than solutions of the neutral salts: but there was very little sensible effect.

The same principles will apply to all the varieties of the electrical apparatus, whether containing double or single plates; and if the ideas developed in the preceding sections be correct, one property operating under different modifications is the universal cause of their activity.

* The experiments proving this fact, and the other analogous facts in this page, may be seen detailed in Nicholson's Journal, 4to vol iv. p 338 and 394; and Phil Mag vol x p 40

† In this process ammonia was rapidly given off from the surface of the negative cone, and nitrous acid from that of the positive cone, and a white vapour was produced by their combination in the atmosphere above the apparatus

X.—ON SOME GENERAL ILLUSTRATIONS AND APPLICATIONS OF THE FOREGOING FACTS AND PRINCIPLES; AND CONCLUSION.

The general ideas advanced in the preceding pages are evidently directly in contradiction to the opinion advanced by Fabroni, and which, in the early stage of the investigation, appeared extremely probable, namely, that chemical changes are the *primary* causes of the phenomena of Galvanism.

Before the experiments of M. Volta on the electricity excited by the mere contact of metals were published, I had to a certain extent adopted this opinion; but the new facts immediately proved that another power must necessarily be concerned; for it was not possible to refer the electricity exhibited by the apposition of metallic surfaces to any chemical alterations, particularly as the effect is more distinct in a dry atmosphere, in which even the most oxidable metals do not change, than in a moist one, in which many metals undergo chemical alteration.

Other facts likewise soon occurred demonstrative of the same thing. In the Voltaic combination of diluted nitrous acid, zinc and copper, as is well known, the side of the zinc exposed to the acid is positive. But in combinations of zinc, water, and diluted nitric acid, the surface exposed to the acid is negative; though if the *chemical* action of the acid on the zinc had been the cause of the effect, it ought to be the same in both cases.

In mere cases of chemical change, likewise, electricity is never exhibited. Iron burned in oxygen gas, properly connected with a condensing electrometer, gives no charge to it during the process. Nitre and charcoal deflagrated in communication with the same instrument do not by their agencies in the slightest degree affect the gold leaves. Solid pure potash and sulphuric acid made to combine in an insulated platina crucible produce no electrical appearances. A solid amalgam of bismuth and a solid amalgam of lead become fluid when mixed together: the experiment, I find, is connected with a diminution of temperature, but with no exhibition of electrical effects. A thin plate of zinc, after being placed upon a surface of mercury, and separated by an insulated body, is found positive, the mercury is negative: the effects are exalted by heating the metals: but let them be kept in contact sufficiently long to amalgamate, and the compound gives no signs of electricity. I could mention a great number of other instances of *pure chemical* action in which I have used all the means in my power to ascertain the fact, and the result has been constantly the same. In cases of effervescence, indeed, particularly when accompanied by much heat, the metallic vessels employed become negative, but this is a phenomenon connected with *evaporation*, the change of state of a body independent of chemical change, and is to be referred to a different law.*

I mentioned the glass plates of Beccaria as affording a parallel to the case of combination in consequence of the different electrical states of bodies. In Guyton de Morveau's experiments on cohesion, the different metals are said to have adhered to mercury with a force proportional to their chemical affinities. But the other metals have different electrical energies, or different degrees of the same electrical energy with regard to this body; and in all cases of contact of mercury with another metal, upon a large surface, they ought to adhere in consequence of the difference of their electrical states, and that with a force proportional to the

* The change of the capacities of bodies in consequence of the alteration in their volumes, or states of existence by heat, is a continually operating source of electrical effects: and as I have hinted, page 15, it often interferes with the results of experiments on the electrical energies of bodies as exhibited by contact. It is likewise probably one of the sources of the capricious results of experiments of friction, in which the same body, according as its texture is altered, or its temperature changed, assumes different states with regard to another body. Friction may be considered as a succession of contacts, and the natural energies of bodies would probably be accurately exhibited by it, if the unequal excitation of heat or its unequal communication to the different surfaces did not interfere by altering unequally their electrical capacities Of the elements of flint glass, silex is slightly negative with regard to the metals, the soda is positive; and in contacts of glass with metals I find it exhibits the excess of the energy of the alkali: the case, as is well known, is the same in friction, the amalgam of the common machine is essential to its powerful excitation.

exaltation of those states. Iron, which M. Guyton found slightly adhesive, I find exhibits little positive electricity after being laid upon a surface of mercury, and then separated. Tin, zinc, and copper, which adhere much more strongly, communicate higher charges to the condensing electrometer: I have had no instrument sufficiently exact to measure the differences: but it would seem that the adhesion from the difference of electrical states must have operated in these experiments,* which, being proportional to the electrical energies, are, on the hypothesis before stated, proportional to the chemical affinities. How far cohesion in general may be influenced or occasioned by this effect of the difference of the electrical energies of bodies is a curious question for investigation.

Many applications of the general facts and principles to the processes of chemistry, both in art and in nature, will readily suggest themselves to the philosophical inquirer.

They offer very easy methods of separating acid and alkaline matter, when they exist in combination, either together or separately, in minerals; and the electrical powers of decomposition may be easily employed in animal and vegetable analysis.

A piece of muscular fibre, of two inches long and half an inch in diameter, after being electrified by the power of 150 for five days, became perfectly dry and hard, and left on incineration no saline matter. Potash, soda, ammonia, lime, and oxide of iron were evolved from it on the negative side, and the three common mineral acids and the phosphoric acid, were given out on the positive side.

A laurel leaf, treated in the same manner, appeared as if it had been exposed to a heat of 500° or 600° Fahrenheit, and was brown and parched. Green colouring matter, with resin, alkali, and lime, appeared in the negative vessel: and the positive vessel contained a clear fluid, which had the smell of peach blossoms; and when neutralised by potash, gave a blue-green precipitate to solution of sulphate of iron; so that it contained vegetable prussic acid.

A small plant of mint, in a state of healthy vegetation, was made the medium of connection in the battery, its extremities being in contact with pure water; the process was carried on for 10 minutes: potash and lime were found in the negatively electrified water, and acid matter in the positively electrified water, which occasioned a precipitate in solutions of muriate of barytes, nitrate of silver, and muriate of lime. This plant recovered after the process: but a similar one, that had been electrified for four hours with like results, faded and died.† The facts show that the electrical powers of decomposition act even upon living vegetable matter: and there are some phenomena which seem to prove that they operate likewise upon living animal systems. When the fingers, after having been carefully washed with pure water, are brought in contact with this fluid in the positive part of the circuit, acid matter is rapidly developed, having the characters of a mixture of muriatic, phosphoric, and sulphuric acids: and if a similar trial be made in the negative part, fixed alkaline matter is as quickly exhibited.

The acid and alkaline tastes produced upon the tongue, in Galvanic experiments, seem to depend upon the decomposition of the saline matter contained in the living animal substance, and perhaps in the saliva.

As acid and alkaline substances are capable of being separated from their combinations in living systems by electrical powers, there is every reason to believe that by converse methods they may be likewise introduced into the animal economy, or made to pass through the animal organs: and the same thing may be supposed of metallic oxides; and these ideas ought to lead to some new investigations in medicine and physiology.

It is not improbable that the electrical decomposition of the neutral salts in different cases may admit of economical uses. Well burned charcoal and plumbago, or charcoal and iron, might be made the exciting powers; and such an

* Amalgamation undoubtedly must have interfered; but the *general* result seems to have been distinct.

† Seeds, I find, when placed in pure water in the positive part of the circuit, germinate much more rapidly than under common circumstances; but in the negative part of the circuit they do not germinate at all. Without supposing any peculiar effects from the different electricities, which however *may* operate, the phenomenon may be accounted for from the saturation of the water near the positive metallic surface with oxygen, and of that near the negative surface with hydrogen.

arrangement, if erected upon an extensive scale, neutrosaline matter being employed in every series would, there is every reason to believe, produce large quantities of acids and alkalies with very little trouble or expense.

Ammonia and acids, capable of decomposition, undergo chemical change in the Voltaic circuit only when they are in very concentrated solution, and in other cases are merely carried to their particular points of rest. This fact may induce us to hope that the new mode of analysis may lead us to the discovery of the *true* elements of bodies, if the materials acted on be employed in a certain state of concentration, and the electricity be sufficiently exalted. For if chemical union be of the nature which I have ventured to suppose, however strong the natural electrical energies of the elements of bodies may be, yet there is every probability of a limit to their strength: whereas the powers of our artificial instruments seem capable of indefinite increase.

Alterations of electrical equilibrium are continually taking place in nature; and it is probable that this influence, in its faculties of decomposition and transference, considerably interferes with the chemical alterations occurring in different parts of our system.

The electrical appearances which precede earthquakes and volcanic eruptions, and which have been described by the greater number of observers of these awful events, admit of very easy explanation on the principles that have been stated.

Besides the cases of sudden and violent change, there must be constant and tranquil alterations in which electricity is concerned, produced in various parts of the interior strata of our globe.

Where pyritous strata and strata of coal-blende occur, where the pure metals or the sulphurets are found in contact with each other, or any conducting substances, and where different strata contain different saline menstrua, electricity must be continually manifested; and it is very probable, that many mineral formations have been materially influenced, or even occasioned by its agencies.

In an experiment that I made of electrifying a mixed solution of muriates of iron, of copper, of tin, and of cobalt, in a positive vessel, distilled water being in a negative vessel, all the four oxides passed along the asbestus, and into the negative tube, and a yellow metallic crust formed on the wire, and the oxides arranged themselves in a mixed state round the base of it.

In another experiment, in which carbonate of copper was diffused through water in a state of minute division, and a negative wire placed in a small perforated cube of zeolite in the water, green crystals collected round the cube; the particles not being capable of penetrating it.

By a multiplication of such instances, the electrical power of transference may be easily conceived to apply to the explanation of some of the principal and most mysterious facts in geology.

And by imagining a scale of feeble powers, it would be easy to account for the association of the insoluble metallic and earthy compounds, containing acids.

Natural electricity has hitherto been little investigated, except in the case of its evident and powerful concentration in the atmosphere.

Its slow and silent operations in every part of the surface will probably be found more immediately and importantly connected with the order and economy of nature; and investigations on this subject can hardly fail to enlighten our philosophical systems of the earth; and may possibly place new powers within our reach.

II.

THE BAKERIAN LECTURE FOR 1807.

ON SOME NEW PHENOMENA OF CHEMICAL CHANGES PRODUCED BY ELECTRICITY, PARTICULARLY THE DECOMPOSITION OF THE FIXED ALKALIES, AND THE EXHIBITION OF THE NEW SUBSTANCES WHICH CONSTITUTE THEIR BASES; AND ON THE GENERAL NATURE OF ALKALINE BODIES.

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I.—INTRODUCTION.

IN the Bakerian Lecture which I had the honour of presenting to the Royal Society last year, I described a number of decompositions and chemical changes produced in substances of known composition by electricity, and I ventured to conclude, from the general principles on which the phenomena were capable of being explained, that the new methods of investigation promised to lead to a more intimate knowledge than had hitherto been obtained, concerning the true elements of bodies.

This conjecture, then sanctioned only by strong analogies, I am now happy to be able to support by some conclusive facts. In the course of a laborious experimental application of the powers of electro-chemical analysis, to bodies which have appeared simple when examined by common chemical agents, or which, at least, have never been decomposed, it has been my good fortune to obtain new and singular results.

Such of the experiments as are in a tolerably mature state, and capable of being arranged in a connected order, I shall detail in the following sections, particularly those which demonstrate the decomposition and composition of the fixed alkalies, and the production of the new and extraordinary bodies which constitute their bases.

In speaking of novel methods of investigation, I shall not fear to be minute. When the common means of chemical research have been employed, I shall mention only results. A historical detail of the progress of the investigation, of all the difficulties that occurred, and of the manner in which they were overcome, and of all the manipulations employed, would far exceed the limits assigned to this Lecture. It is proper to state, however, that, when general facts are mentioned, they are such only as have been deduced from processes carefully performed and often repeated.

II.—ON THE METHODS USED FOR THE DECOMPOSITION OF THE FIXED ALKALIES.

The researches I had made on the decomposition of acids, and of alkaline and earthy neutral compounds, proved that the powers of electrical decomposition were proportional to the strength of the opposite electricities in the circuit, and to the conducting power and degree of concentration of the materials employed.

In the first attempts that I made on the decomposition of the fixed alkalies, I acted upon aqueous solutions of potash and soda, saturated at common temperatures, by the highest electrical power I could command, and which was produced

by a combination of Voltaic batteries belonging to the Royal Institution, containing 24 plates of copper and zinc of 12 inches square, 100 plates of 6 inches, and 150 of 4 inches square, charged with solutions of alum and nitrous acid; but in these cases, though there was a high intensity of action, the water of the solutions alone was affected, and hydrogen and oxygen disengaged with the production of much heat and violent effervescence.

The presence of water appearing thus to prevent any decomposition, I used potash in igneous fusion. By means of a stream of oxygen gas from a gasometer applied to the flame of a spirit lamp, which was thrown on a platina spoon containing potash, this alkali was kept for some minutes in a strong red heat, and in a state of perfect fluidity. The spoon was preserved in communication with the positive side of the battery of the power of 100 of 6 inches, highly charged; and the connection from the negative side was made by a platina wire.

By this arrangement some brilliant phenomena were produced. The potash appeared a conductor in a high degree, and as long as the communication was preserved, a most intense light was exhibited at the negative wire, and a column of flame, which seemed to be owing to the developement of combustible matter, arose from the point of contact.

When the order was changed, so that the platina spoon was made negative, a vivid and constant light appeared at the opposite point: there was no effect of inflammation round it; but aeriform globules, which inflamed in the atmosphere, rose through the potash.

The platina, as might have been expected, was considerably acted upon; and in the cases when it had been negative, in the highest degree.

The alkali was apparently dry in this experiment; and it seemed probable that the inflammable matter arose from its decomposition. The residual potash was unaltered; it contained indeed a number of dark grey metallic particles, but these proved to be derived from the platina.

I tried several experiments on the electrization of potash rendered fluid by heat, with the hopes of being able to collect the combustible matter, but without success; and I only attained my object by employing electricity as the common agent for fusion and decomposition.

Though potash, perfectly dried by ignition, is a non-conductor, yet it is rendered a conductor by a very slight addition of moisture, which does not perceptibly destroy its aggregation; and in this state it readily fuses and decomposes by strong electrical powers.

A small piece of pure potash, which had been exposed for a few seconds to the atmosphere, so as to give conducting power to the surface, was placed upon an insulated disc of platina, connected with the negative side of the battery of the power of 250 of 6 and 4, in a state of intense activity; and a platina wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. The whole apparatus was in the open atmosphere.

Under these circumstances a vivid action was soon observed to take place. The potash began to fuse at both its points of electrization. There was a violent effervescence at the upper surface; at the lower, or negative surface, there was no liberation of elastic fluid; but small globules having a high metallic lustre, and being precisely similar in visible characters to quicksilver, appeared, some of which burnt with explosion and bright flame, as soon as they were formed, and others remained, and were merely tarnished, and finally covered by a white film which formed on their surfaces.

These globules, numerous experiments soon showed to be the substance I was in search of, and a peculiar inflammable principle the basis of potash. I found that the platina was in no way connected with the result, except as the medium for exhibiting the electrical powers of decomposition; and a substance of the same kind was produced when pieces of copper, silver, gold, plumbago, or even charcoal were employed for completing the circuit.

The phenomenon was independent of the presence of air; I found that it took place when the alkali was in the vacuum of an exhausted receiver.

The substance was likewise produced from potash fused by means of a lamp, in glass tubes confined by mercury, and furnished with hermetically inserted platina wires by which the electrical action was transmitted. But this operation could not be carried on for any considerable time; the glass was rapidly dissolved

by the action of the alkali, and this substance soon penetrated through the body of the tube.

Soda, when acted upon in the same manner as potash, exhibited an analogous result: but the decomposition demanded greater intensity of action in the batteries, or the alkali was required to be in much thinner and smaller pieces. With the battery of 100 of 6 inches in full activity I obtained good results from pieces of potash weighing from 40 to 70 grains, and of a thickness which made the distance of the electrified metallic surfaces nearly a quarter of an inch; but with a similar power it was impossible to produce the effects of decomposition on pieces of soda of more than 15 or 20 grains in weight, and that only when the distance between the wires was about one-eighth or one-tenth of an inch.

The substance produced from potash remained fluid at the temperature of the atmosphere at the time of its production; that from soda, which was fluid in the degree of heat of the alkali during its formation, became solid on cooling, and appeared having the lustre of silver.

When the power of 250 was used, with a very high charge for the decomposition of soda, the globules often burnt at the moment of their formation, and sometimes violently exploded and separated into smaller globules, which flew with great velocity through the air in a state of vivid combustion, producing a beautiful effect of continued jets of fire.

III.—THEORY OF THE DECOMPOSITION OF THE FIXED ALKALIES; THEIR COMPOSITION, AND PRODUCTION.

As in all decompositions of compound substances which I had previously examined, at the same time that combustible bases were developed at the negative surface in the electrical circuit, oxygen was produced, and evolved or carried into combination at the positive surface, it was reasonable to conclude that this substance was generated in a similar manner by the electrical action upon the alkalies; and a number of experiments made above mercury, with the apparatus for excluding external air, proved that this was the case.

When solid potash, or soda in its conducting state, was included in glass tubes furnished with electrified platina wires, the new substances were generated at the negative surfaces; the gas given out at the other surface proved by the most delicate examination to be pure oxygen; and unless an excess of water was present no gas was evolved from the negative surface.

In the synthetical experiments, a perfect coincidence likewise will be found.

I mentioned that the metallic lustre of the substance from potash immediately became destroyed in the atmosphere, and that a white crust formed upon it. This crust I soon found to be pure potash, which immediately deliquesced, and new quantities were formed, which in their turn attracted moisture from the atmosphere till the whole globule disappeared, and assumed the form of a saturated solution of potash.*

When globules were placed in appropriate tubes containing common air or oxygen gas confined by mercury, an absorption of oxygen took place; a crust of alkali instantly formed upon the globule; but from the want of moisture for its solution, the process stopped, the interior being defended from the action of the gas.

With the substance from soda, the appearances and effects were analogous.

When the substances were strongly heated, confined in given portions of oxygen, a rapid combustion with a brilliant white flame was produced, and the metallic globules were found converted into a white and solid mass, which in the case of the substance from potash was found to be potash, and in the case of that from soda, soda.

* Water likewise is decomposed in the process. We shall hereafter see that the basis of the fixed alkalies act upon this substance with greater energy than any other known bodies. The minute theory of the oxidation of the bases of the alkalies in the free air, is this:—oxygen gas is first attracted by them, and alkali formed. This alkali speedily absorbs water. This water is again decomposed. Hence, during the conversion of a globule into alkaline solution, there is a constant and rapid disengagement of small quantities of gas.

Oxygen gas was absorbed in this operation, and nothing emitted which affec the purity of the residual air

The alkalies produced were apparently dry, or at least contained no more mc ture than might well be conceived to exist in the oxygen gas absorbed; and th weights considerably exceeded those of the combustible matters consumed.

The processes on which these conclusions are founded will be fully descril hereafter, when the minute details which are necessary will be explained, and proportions of oxygen, and of the respective inflammable substances which en into union to form the fixed alkalies, will be given

It appears, then, that in these facts there is the same evidence for the decom sition of potash and soda into oxygen and two peculiar substances, as there is the decomposition of sulphuric and phosphoric acids and the metallic oxides i oxygen and their respective combustible bases

In the analytical experiments, no substances capable of decomposition are p sent but the alkalies and a minute portion of moisture; which seems in no otl way essential to the result, than in rendering them conductors at the surface: the new substances are not generated till the interior, which is dry, begins to fused; they explode when in rising through the fused alkali they come in cont with the heated moistened surface; they cannot be produced from crystalliz alkalies, which contain much water; and the effect produced by the electrizati of ignited potash, which contains no sensible quantity of water, confirms opinion of their formation independently of the presence of this substance

The combustible bases of the fixed alkalies seem to be repelled as other co bustible substances, by positively electrified surfaces, and attracted by negativ electrified surfaces, and the oxygen follows the contrary order;* or the oxyg being naturally possessed of the negative energy, and the bases of the positive, not remain in combination when either of them is brought into an electrical st opposite to its natural one In the synthesis, on the contrary, the natural en gies or attractions come in equillibrium with each other; and when these are i low state at common temperatures, a slow combination is effected; but when th are exalted by heat, a rapid union is the result; and, as in other like cases, w the production of fire —A number of circumstances relating to the agencies the bases of the alkalies will be immediately stated, and will be found to offer c firmations of these general conclusions.

IV —ON THE PROPERTIES AND NATURE OF THE BASIS OF POTASH

After I had detected the bases of the fixed alkalies, I had considerable difficu to preserve and confine them so as to examine their properties, and submit th to experiments; for, like the *alkahests* imagined by the alchemists, they act more or less upon almost every body to which they were exposed

The fluid substance, amongst all those I have tried, on which I find they ha least effect, is recently distilled naphtha —In this material, when excluded fr the air, they remain for many days without considerably changing, and their ph sical properties may be easily examined in the atmosphere when they are cover by a thin film of it

The basis of potash at 60° Fahrenheit, the temperature in which I first examin it, appeared, as I have already mentioned, in small globules possessing the metal lustre, opacity, and general appearance of mercury; so that when a globule mercury was placed near a globule of the peculiar substance, it was not possil to detect a difference by the eye

At 60° Fahrenheit it is however only imperfectly fluid, for it does not read run into a globule when its shape is altered; at 70° it becomes more fluid; and 100° its fluidity is perfect, so that different globules may be easily made to r into one At 50° Fahrenheit it becomes a soft and malleable solid, which has t lustre of polished silver; and at about the freezing point of water it becom harder and brittle, and when broken in fragments, exhibits a crystallized textu which in the microscope seems composed of beautiful facets of a perfect whitene and high metallic splendour

To be converted into vapour, it requires a temperature approaching that of t

* See Bakerian Lecture, 1806, p 12

red heat; and when the experiment is conducted under proper circumstances, it is found unaltered after distillation.

It is a perfect conductor of electricity When a spark from the Voltaic battery of 100 of 6 inches is taken upon a large globule in the atmosphere, the light is green, and combustion takes place at the point of contact only When a small globule is used, it is completely dissipated with explosion, accompanied by a most vivid flame, into alkaline fumes

It is an excellent conductor of heat

Resembling the metals in all these sensible properties, it is however remarkably different from any of them in specific gravity; I found that it rose to the surface of naphtha distilled from petroleum, and of which the specific gravity was 861, and it did not sink in double distilled naphtha, the specific gravity of which was about 770, that of water being considered as 1 The small quantities in which it is produced by the highest electrical powers, rendered it very difficult to determine this quality with minute precision I endeavoured to gain approximations on this subject by comparing the weights of perfectly equal globules of the basis of potash and mercury I used the very delicate balance of the Royal Institution, which when loaded with the quantities I employed, and of which the mercury never exceeded ten grains, is sensible at least to the 1-2000th of a grain Taking the mean of four experiments, conducted with great care, its specific gravity at 62° Fahrenheit, is to that of mercury as 10 to 223, which gives a proportion to that of water nearly as 6 to 10; so that it is the lightest fluid body known In its solid form it is a little heavier, but even in this state when cooled to 40° Fahrenheit, it swims in the double-distilled naphtha

The chemical relations of the basis of potash are still more extraordinary than its physical ones

I have already mentioned its alkalization and combustion in oxygen gas —It combines with oxygen slowly and without flame at all temperatures that I have tried below that of its evaporization —But at this temperature combustion takes place, and the light is of a brilliant whiteness and the heat intense When heated slowly in a quantity of oxygen gas not sufficient for its complete conversion into potash, and at a temperature inadequate to its inflammation, 400° Fahrenheit, for instance, its tint changes to that of a red brown, and when the heat is withdrawn, all the oxygen is found to be absorbed, and a solid is formed of a greyish colour, which partly consists of potash and partly of the basis of potash in a lower degree of oxigenation,—and which becomes potash by being exposed to water, or by being again heated in fresh quantities of air

The substance consisting of the basis of potash combined with an under proportion of oxygen, may likewise be formed by fusing dry potash and its basis together under proper circumstances —The basis rapidly loses its metallic splendour; the two substances unite into a compound, of a red brown colour when fluid, and of a dark grey hue when solid; and this compound soon absorbs its full proportion of oxygen when exposed to the air, and is wholly converted into potash

And the same body is often formed in the analytical experiments when the action of the electricity is intense, and the potash much heated

The basis of potash, when introduced into oxymuriatic acid gas, burns spontaneously with a bright red light, and a white salt proving to be muriate of potash is formed

When a globule is heated in hydrogen at a degree below its point of vaporization, it seems to dissolve in it, for the globule diminishes in volume, and the gas explodes with alkaline fumes and bright light, when suffered to pass into the air; but by cooling, this spontaneous detonating property is destroyed, and the basis is either wholly or principally deposited

The action of the basis of potash on water exposed to the atmosphere is connected with some beautiful phenomena. When it is thrown upon water, or when it is brought into contact with a drop of water at common temperatures, it decomposes it with great violence, an instantaneous explosion is produced with brilliant flame, and a solution of pure potash is the result

In experiments of this kind, an appearance often occurs similar to that produced by the combustion of phosphuretted hydrogen; a white ring of smoke, which gradually extends as it rises into the air.

When water is made to act upon the basis of potash out of the contact of air

and preserved by means of a glass tube under naphtha, the decomposition is violent; and there is much heat and noise, but no luminous appearance, and the gas evolved when examined in the mercurial or water pneumatic apparatus is found to be pure hydrogen.

When a globule of the basis of potash is placed upon ice, it instantly burns with a bright flame, and a deep hole is made in the ice, which is found to contain a solution of potash.

The theory of the action of the basis of potash upon water exposed to the atmosphere, though complicated changes occur, is far from being obscure. The phenomena seem to depend on the strong attractions of the basis for oxygen and of the potash formed for water. The heat, which arises from two causes, decomposition and combination, is sufficiently intense to produce the inflammation. Water is a bad conductor of heat; the globule swims exposed to air; a part of it, there is the greatest reason to believe, is dissolved by the heated nascent hydrogen; and this substance being capable of spontaneous inflammation, explodes, and communicates the effect of combustion to any of the basis that may be yet uncombined.

When a globule confined out of the contact of air is acted upon by water, the theory of decomposition is very simple, the heat produced is rapidly carried off, so that there is no ignition; and a high temperature being requisite for the solution of the basis in hydrogen, this combination probably does not take place, or at least it can have a momentary existence only.

The production of alkali in the decomposition of water by the basis of potash is demonstrated in a very simple and satisfactory manner by dropping a globule of it upon moistened paper tinged with turmeric. At the moment that the globule comes into contact with the water, it burns, and moves rapidly upon the paper, as if in search of moisture, leaving behind it a deep reddish brown trace, and acting upon the paper precisely as dry caustic potash.

So strong is the attraction of the basis of potash for oxygen, and so great the energy of its action upon water, that it discovers and decomposes the small quantities of water contained in alcohol and ether, even when they are carefully purified.

In ether this decomposition is connected with an instructive result. Potash is insoluble in this fluid; and when the basis of potash is thrown into it, oxygen is furnished to it, and hydrogen gas disengaged, and the alkali as it forms renders the ether white and turbid.

In both these inflammable compounds the energy of its action is proportional to the quantity of water they contain, and hydrogen and potash are the constant result.

The basis of potash, when thrown into solutions of the mineral acids, inflames and burns on the surface. When it is plunged by proper means beneath the surface enveloped in potash, surrounded by naphtha, it acts upon the oxygen with the greatest intensity, and all its effects are such as may be explained from its strong affinity for this substance. In sulphuric acid a white saline substance with a yellow coating, which is probably sulphate of potash surrounded by sulphur, and a gas which has the smell of sulphurous acid, and which probably is a mixture of that substance with hydrogen gas, are formed. In nitrous acid, nitrous gas is disengaged, and nitrate of potash formed.

The basis of potash readily combines with the simple inflammable solids, and with the metals; with phosphorus and sulphur, it forms compounds similar to the metallic phosphurets and sulphurets.

When it is brought in contact with a piece of phosphorus, and pressed upon, there is a considerable action: they become fluid together, burn, and produce phosphate of potash. When the experiment is made under naphtha, their combination takes place without the liberation of any elastic matter, and they form a compound which has a considerably higher point of fusion than its two constituents, and which remains a soft solid in boiling naphtha. In its appearance it perfectly agrees with a metallic phosphuret, it is of the colour of lead, and when spread out, has a lustre similar to polished lead. When exposed to air of common temperatures, it slowly combines with oxygen, and becomes phosphate of potash. When heated upon a plate of platina, fumes exhale from it, and it does not burn till it attains the temperature of the rapid combustion of the basis of potash.

When the basis of potash is brought in contact with sulphur in fusion, in tubes filled with the vapour of naphtha, they combine rapidly with the evolution of heat

and light, and a grey substance, in appearance like artificial sulphuret of iron, is formed, which if kept in fusion, rapidly dissolves the glass, and becomes bright brown. When this experiment is made in a glass tube hermetically sealed, no gas is liberated if the tube is opened under mercury; but when it is made in a tube connected with a mercurial apparatus, a small quantity of sulphuretted hydrogen is evolved, so that the phenomena are similar to those produced by the union of sulphur with the metals in which sulphuretted hydrogen is likewise disengaged, except that the ignition is stronger.* When the union is effected in the atmosphere, a great inflammation takes place, and sulphuret of potash is formed. The sulphuretted basis likewise gradually becomes oxigenated by exposure to the air, and is finally converted into sulphate.

The new substance produces some extraordinary and beautiful results with mercury. When one part of it is added to eight or ten parts of mercury in volume at 60° Fahrenheit, they instantly unite and form a substance exactly like mercury in colour, but which seems to have less coherence, for small portions of it appear as flattened spheres. When a globule is made to touch a globule of mercury about twice as large, they combine with considerable heat; the compound is fluid at the temperature of its formation; but when cool it appears as a solid metal, similar in colour to silver. If the quantity of the basis of potash is still farther increased, so as to be about 1-30th the weight of the mercury, the amalgam increases in hardness, and becomes brittle. The solid amalgam, in which the basis is in the smallest proportion, seems to consist of about one part in weight of basis and seventy parts of mercury, and is very soft and malleable.

When these compounds are exposed to air, they rapidly absorb oxygen; potash which deliquesces is formed; and in a few minutes the mercury is found pure and unaltered.

When a globule of the amalgam is thrown into water, it rapidly decomposes it with a hissing noise; potash is formed, pure hydrogen disengaged, and the mercury remains free.

The fluid amalgam of mercury and this substance dissolves all the metals I have exposed to it; and in this state of union, mercury acts on iron and platina.

When the basis of potash is heated with gold, or silver, or copper, in a close vessel of pure glass, it rapidly acts upon them; and when the compounds are thrown into water, this fluid is decomposed, potash formed, and the metals appear to be separated unaltered.

The basis of potash combines with fusible metal, and forms an alloy with it, which has a higher point of fusion than the fusible metal.

The action of the basis of potash upon the inflammable oily compound bodies, confirms the other facts of the strength of its attraction for oxygen.

On naphtha colourless and recently distilled, as I have already said, it has very little power of action; but in naphtha that has been exposed to the air it soon oxidates, and alkali is formed, which unites with the naphtha into a brown soap that collects round the globule.

On the concrete oils (tallow, spermaceti, wax, for instance), when heated, it acts slowly, coaly matter is deposited, a little gas† is evolved, and a soap is

* The existence of hydrogen in sulphur, is rendered very probable by the ingenious researches of M. Berthollet, Jun., Annales de Chimie, Fevrier 1807, page 143. The fact is almost demonstrated by an experiment which I saw made by W. Clayfield, Esq. at Bristol, in 1799. Copper filings and powdered sulphur, in weight in the proportion of three to one, rendered very dry, were heated together in a retort, connected with a mercurial pneumatic apparatus. At the moment of combination, a quantity of elastic fluid was liberated, amounting to nine or ten times the volume of the materials employed, and which consisted of sulphuretted hydrogen mixed with sulphurous acid. The first mentioned product, there is every reason to believe, must be referred to the sulphur, the last probably to the copper, which it is easy to conceive may have become slightly and superficially oxidated during the processes of filing and drying by heat.

† When a globule of the basis of potash is introduced into any of the fixed oils heated, the first product is pure hydrogen, which arises from the decomposition of the water absorbed by the crust of potash during the exposure to the atmosphere. The gas evolved, when the globule is freed from this crust, I have found to be carbonated hydrogen, requiring more than an equal bulk of oxygen gas for its complete saturation by explosion. I have made a great number of experiments, which it would be foreign to the object of

formed; but in these cases it is necessary that a large quantity of the oil be employed. On the fluid fixed oils it produces the same effects, but more slowly.

By heat likewise it rapidly decomposes the volatile oils; alkali is formed, a small quantity of gas is evolved, and charcoal is deposited.

When the basis of potash is thrown into camphor in fusion, the camphor soon becomes blackened, no gas is liberated in the process of decomposition, and a saponaceous compound is formed; which seems to show that camphor contains more oxygen than the volatile oils.

The basis of potash readily reduces metallic oxides when heated in contact with them. When a small quantity of the oxide of iron was heated with it, to a temperature approaching its point of distillation, there was a vivid action; alkali and grey metallic particles, which dissolved with effervescence in muriatic acid, appeared. The oxides of lead and the oxides of tin were revived still more rapidly; and when the basis of potash was in excess, an alloy was formed with the revived metal.

In consequence of this property, the basis of potash readily decomposes flint glass and green glass, by a gentle heat; alkali is immediately formed by oxygen from the oxides, which dissolves the glass, and a new surface is soon exposed to the agent.

At a red heat, even the purest glass is altered by the basis of potash: the oxygen in the alkali of the glass seems to be divided between the two bases, the basis of potash and the alkaline basis in the glass, and oxides, in the first degree of oxigenation, are the result.

When the basis of potash is heated in tubes made of plate glass filled with the vapour of naphtha, it first acts upon the small quantity of the oxides of cobalt and manganese in the interior surface of the glass, and a portion of alkali is formed. As the heat approaches to redness, it begins to rise in vapour, and condenses in the colder parts of the tube; but at the point where the heat is strongest, a part of the vapour seems to penetrate the glass, rendering it of a deep red brown colour; and by repeatedly distilling and heating the substance in a close tube of this kind, it finally loses its metallic form, and a thick brown crust, which slowly decomposes water, and which combines with oxygen when exposed to air forming alkali, lines the interior of the tube, and in many parts is found penetrating through its substance.*

In my first experiments on the distillation of the basis of potash, I had great difficulty in accounting for these phenomena; but the knowledge of the substance it forms in its first degree of union with oxygen, afforded a satisfactory explanation.

V.—ON THE PROPERTIES AND NATURE OF THE BASIS OF SODA.

The basis of soda, as I have already mentioned, is a solid at common temperatures. It is white, opaque, and when examined under a film of naphtha, has the lustre and general appearance of silver. It is exceedingly malleable, and is much softer than any of the common metallic substances. When pressed upon by a platina blade, with a small force, it spreads into thin leaves, and a globule of the 1-10th or 1-12th of an inch in diameter is easily spread over a surface of a quarter of an inch,† and this property does not diminish when it is cooled to 32° Fahrenheit.

this lecture to give in minute detail, on the agencies of the basis of potash on the oils. Some anomalies occurred which led to the inquiry, and the result was perfectly conclusive. Olive oil, oil of turpentine, and naphtha, when decomposed by heat, exhibited as products different portions of charcoal, heavy inflammable gas, empyreumatic oily matter, and water, so that the existence of oxygen in them was fully proved; and accurate indications of the proportions of their elements might be gained by their decomposition by the basis of potash. Naphtha of all furnished least water and carbonate acid, and oil of turpentine the most.

* This is the obvious explanation in the present state of our knowledge; but it is more than probable that the silex of the glass likewise suffers some change, and probably decomposition. This subject I hope to be able to resume on another occasion.

† Globules may be easily made to adhere and form one mass by strong pressure: so that the property of welding, which belongs to iron and platina at a white heat only, is possessed by this substance at common temperatures.

It conducts electricity and heat in a similar manner to the basis of potash; and small globules of it inflame by the voltaic electrical spark, and burn with bright explosions.

Its specific gravity is less than that of water. It swims in oil of sassafras of 1·096, water being 1, and sinks in naphtha of specific gravity ·861. This circumstance enabled me to ascertain the point with precision. I mixed together oil of sassafras and naphtha, which combine very perfectly, observing the proportions till I had composed a fluid, in which it remained at rest above or below; and this fluid consisted of nearly twelve parts naphtha, and five of oil of sassafras, which gives a specific gravity to that of water, nearly as nine to ten, or more accurately as ·9348 to 1.

The basis of soda has a much higher point of fusion than the basis of potash; its parts begin to lose their cohesion at about 120° Fahrenheit, and it is a perfect fluid at about 180°, so that it readily fuses under boiling naphtha.

I have not yet been able to ascertain at what degree of heat it is volatile; but it remains fixed in a state of ignition at the point of fusion of plate glass.

The chemical phenomena produced by the basis of soda are analogous to those produced by the basis of potash; but with such characteristic differences as might be well expected.

When the basis of soda is exposed to the atmosphere, it immediately tarnishes, and by degrees becomes covered with a white crust, which deliquesces much more slowly than the substance which forms on the basis of potash. It proves, on minute examination, to be pure soda.

The basis of soda combines with oxygen slowly, and without luminous appearance at all common temperatures; and when heated this combination becomes more rapid; but no light is emitted till it has acquired a temperature nearly that of ignition.

The flame that it produces in oxygen gas is white, and it sends forth bright sparks, occasioning a very beautiful effect; in common air it burns with light of the colour of that produced during the combustion of charcoal, but much brighter.

The basis of soda, when heated in hydrogen, seemed to have no action upon it. When introduced into oxymuriatic acid gas, it burned vividly with numerous scintillations of a bright red colour. Saline matter was formed in this combustion, which, as might have been expected, proved to be muriate of soda.

Its operation upon water offers most satisfactory evidence of its nature. When thrown upon this fluid, it produces a violent effervescence, with a loud hissing noise; it combines with the oxygen of the water to form soda, which is dissolved, and its hydrogen is disengaged. In this operation there is no luminous appearance; and it seems probable that even in the nascent state hydrogen is incapable of combining with it.*

When the basis of soda is thrown into hot water, the decomposition is more violent, and in this case a few scintillations are generally observed at the surface of the fluid; but this is owing to small particles of the basis, which are thrown out of the water sufficiently heated, to burn in passing through the atmosphere. When, however, a globule is brought in contact with a small particle of water, or with moistened paper, the heat produced (there being no medium to carry it off rapidly) is usually sufficient for the accension of the basis.

The basis of soda acts upon alcohol and ether precisely in a similar manner with the basis of potash. The water that they contain is decomposed; soda is rapidly formed, and hydrogen disengaged.

The basis of soda, when thrown upon the strong acids, acts upon them with great energy. When nitrous acid is employed, a vivid inflammation is produced; with muriatic and sulphuric acid there is much heat generated, but no light.

When plunged, by proper means, beneath the surface of the acids, it is rapidly oxigenated; soda is produced, and the other educts are similar to those generated by the action of the basis of potash.

With respect to the fixed and volatile oils and naphtha in their different states, there is a perfect coincidence between the effects of the two new substances,

* The more volatile metals only seem capable of uniting with hydrogen; a circumstance presenting an analogy.

except in the difference of the appearances of the saponaceous compounds formed: those produced by the oxidation and combination of the basis of soda being of a darker colour, and apparently less soluble.

The basis of soda, in its degrees of oxidation, has precisely similar habits with the basis of potash

When it is fused with dry soda, in certain quantities, there is a division of oxygen between the alkali and the base; and a deep brown fluid is produced, which becomes a dark grey solid on cooling, and which attracts oxygen from the air, or which decomposes water, and becomes soda.

The same body is often formed in the analytical processes of decomposition, and it is generated when the basis of soda is fused in tubes of the purest plate glass.

There is scarcely any difference in the visible phenomena of the agencies of the basis of soda, and that of potash on sulphur, phosphorus, and the metals.

It combines with sulphur in close vessels filled with the vapour of naphtha with great vividness, with light, heat, and often with explosion from the vaporization of a portion of sulphur, and the disengagement of sulphuretted hydrogen gas. The sulphuretted basis of soda is of a deep grey colour.

The phosphuret has the appearance of lead, and forms phosphate of soda by exposure to air, or by combustion.

The basis of soda in the quantity of one-fortieth, renders mercury a fixed solid of the colour of silver, and the combination is attended with a considerable degree of heat.

It makes an alloy with tin, without changing its colour, and it acts upon lead and gold when heated. I have not examined its habitudes with any other metals, but in its state of alloy it is soon converted into soda by exposure to air, or by the action of water, which it decomposes, with the evolution of hydrogen.

The amalgam of mercury and the basis of soda, seems to form triple compounds with other metals I have tried iron and platina, which I am inclined to believe remain in combination with the mercury, when it is deprived of the new substance by exposure to air.

The amalgam of the basis of soda and mercury likewise combines with sulphur and forms a triple compound of a dark grey colour.

VI.—ON THE PROPORTIONS OF THE PECULIAR BASES AND OXYGEN IN POTASH AND SODA.

The facility of combustion of the bases of the alkalies, and the readiness with which they decomposed water, offered means fully adequate for determining the proportions of the ponderable constituent parts.

I shall mention the general methods of the experiments, and the results obtained by the different series, which approach as near to each other as can be expected in operations performed on such small quantities of materials.

For the process in oxygen gas, I employed glass tubes containing small trays made of thin leaves of silver or other noble metals, on which the substance to be burned, after being accurately weighed or compared with a globule of mercury, equal in size,* was placed: the tube was small at one end, curved, and brought to a fine point, but suffered to remain open; and the other end was fitted to a tube communicating with a gasometer, from which the oxygen gas was introduced, for neither water nor mercury could be used for filling the apparatus. The oxygen gas was carried through the tube till it was found that the whole of the common air was expelled. The degree of its purity was ascertained by suffering a small quantity to pass into the mercurial apparatus. The lower orifice was then hermetically sealed by a spirit lamp, and the upper part drawn out and finally closed, when the aperture was so small, as to render the temperature employed incapable of materially influencing the volume of the gas; and when the whole arrangement was made, the combination was effected by applying heat to the glass in contact with the metallic tray.

* When the globules were very small, the comparison with mercury, which may be quickly made by means of a micrometer, was generally employed as the means of ascertaining the weight: for in this case the globule could be immediately introduced into the tube, and the weight of mercury ascertained at leisure.

In performing these experiments many difficulties occurred. When the flame of the lamp was immediately brought to play upon the glass, the combustion was very vivid, so as sometimes to break the tube; and the alkali generated partly rose in white fumes, which were deposited upon the glass.

When the temperature was slowly raised, the bases of the alkalies acted upon the metallic tray and formed alloys, and in this state it was very difficult to combine them with their full proportion of oxygen; and glass alone could not be employed on account of its decomposition by the alkaline bases; and porcelain is so bad a conductor of heat, that it was not possible to raise it to the point required for the process, without softening the glass.

In all cases the globules of the alkaline bases were carefully freed from naphtha before they were introduced; of course a slight crust of alkali was formed before the combustion, but this could not materially affect the result; and when such a precaution was not used, an explosion generally took place from the evaporization and decomposition of the film of naphtha surrounding the globule.

After the combustion, the absorption of gas was ascertained, by opening the lower point of the tube under water or mercury. In some cases the purity of the residual air was ascertained, in others the alkali formed in the tray was weighed.

From several experiments on the synthesis of potash by combustion, I shall select two, which were made with every possible attention to accuracy, and under favourable circumstances, for a mean result.

In the first experiment 0·12 grain of the basis were employed. The combustion was made upon platina, and was rapid and complete; and the basis appeared to be perfectly saturated, as no disengagement of hydrogen took place when the platina tray was thrown into water. The oxygen gas absorbed equalled in volume 190 grain measures of quicksilver; barometer being at 29·6 inches, thermometer 62° Fahrenheit; and this reduced to a temperature of 60° Fahrenheit, and under a pressure equal to that indicated by 30 inches,* would become 186·67 measures, the weight of which would be about ·0184 grain troy;† but ·0184: ·1384 : : 13·29 : 100; and according to this estimation 100 parts of potash will consist of 86·8 basis, and 13·3 oxygen nearly.

In the second experiment ·07 grain of the basis absorbed at temperature 63° of Fahrenheit, and under pressure equal to 30·1 barometer inches, a quantity of oxygen equal in volume to 121 grain measures of mercury, and the proper corrections being made as in the former case, this gas would weigh ·01189 grain.

But as ·07 + ·01189 = ·08189 : 07 : : 100 : 85·48 nearly, and 100 parts of potash will consist of 85·5 of basis and 14·5 of oxygen nearly. And the mean of the two experiments will be 86·1 of basis to 13·9 of oxygen for 100 parts.

In the most accurate experiment that I made on the combustion of the basis of soda, ·08 parts of the basis absorbed a quantity of oxygen equal to 206 grain measures of mercury; the thermometer being at 56° Fahrenheit; and the barometer at 29·4; and this quantity, the corrections being made as before for the mean temperature and pressure, equals about ·02 parts of oxygen.

And as ·08 + ·02 = ·10 : ·08 : : 100 : 80, and 100 parts of soda, according to this estimation, will consist of 80 basis to 20 of oxygen.

In all cases of slow combustion, in which the alkalies were not carried out of the tray, I found a considerable increase of weight, but as it was impossible to weigh them except in the atmosphere, the moisture attracted rendered the results doubtful; and the proportions from the weight of the oxygen absorbed are more to be depended on. In the experiments in which the processes of weighing were most speedily performed, and in which no alkali adhered to the tube, the basis of potash gained nearly 2 parts for 10, and that of soda between 3 and 4 parts.

* In the correction for temperature, the estimations of Dalton and Gay Lussac are taken, which make gases expand about 1-480th of the primitive volume for every degree of Fahrenheit.

† From experiments that I made in 1799, on the specific gravity of oxygen gas, it would appear that its weight is to that of water as 1 to 748, and to that of quicksilver as 1 to 10142, Researches Chem. and Phil. p. 9; and with this estimation, that deducible from the late accurate researches of Messrs. Allen and Pepys on the Combustion of the Diamond almost precisely agrees, Phil. Trans. 1807, p. 275.

The results of the decomposition of water by the basis of the alkalies were much more readily and perfectly obtained than those of their combustion.

To check the rapidity of the process, and, in the case of potash, to prevent any of the basis from being dissolved, I employed the amalgams with mercury. I used a known weight of the basis, and made the amalgams under naphtha, using about two parts of mercury in volume to one of basis.

In the first instances I placed the amalgams under tubes filled with naphtha, and inverted in glasses of naphtha, and slowly admitted water to the amalgam at the bottom of the glass; but this precaution I soon found unnecessary, for the action of the water was not so intense but that the hydrogen gas could be wholly collected.

I shall give an account of the most accurate experiments made on the decomposition of water by the bases of potash and soda.

In an experiment on the basis of potash conducted with every attention that I could pay to the minutiæ of the operations, hydrogen gas, equal in volume to 298 grains of mercury, were disengaged by the action of ·08 grain of the basis of potash which had been amalgamated with about 3 grains of mercury. The thermometer at the end of the process indicated a temperature of 56° Fahrenheit, and the barometer an atmospheric pressure equal to 29·6 inches.

Now this quantity of hydrogen* would require for its combustion a volume of oxygen gas about equal to that occupied by 154·9 grains of mercury which gives the weight of oxygen required to saturate the ·08 grains of the basis of potash at the mean temperature and pressure nearly ·0151 grain. And 0·8 + ·0151 = ·0951 : ·08 : : 100 : 84·1 nearly.

And according to these indications 100 parts of potash consist of about 84 basis and 16 oxygen.

In an experiment on the decomposition of water by the basis of soda, the mercury in the barometer standing at 30·4 inches, and in the thermometer at 52° Fahrenheit, the volume of hydrogen gas evolved by the action of ·054 grain of basis equalled that of 326 grains of quicksilver. Now this at the mean temperature and pressure would require for its conversion into water, ·0172 of oxygen, and ·054 + ·0172 = ·0712 : ·054 : : 100 : 76 nearly; and according to these indications, 100 parts of soda consist of nearly 76 basis, and 24 oxygen.

In another experiment made with very great care, ·052 of the basis of soda were used; the mercury in the barometer was at 29·9 inches, and that in the thermometer at 58° Fahrenheit. The volume of hydrogen evolved was equal to that of 302 grains of mercury; which would demand for its saturation by combustion, at the mean temperature and pressure ·01549 grain of oxygen; and 100 parts of soda, according to this proportion, would consist nearly of 77 basis and 23 oxygen.

The experiments which have been just detailed, are those in which the largest quantities of materials were employed; I have compared their results, however, with the results of several others, in which the decomposition of water was performed with great care, but in which the proportion of the bases was still more minute: the largest quantity of oxygen indicated by these experiments was, for potash 17, and for soda 26 parts in 100, and the smallest 13, and 19; and comparing all the estimations, it will probably be a good approximation to the truth, to consider potash as composed of about 6 parts basis and 1 of oxygen; and soda, as consisting of 7 basis and 2 oxygen.

VII. — SOME GENERAL OBSERVATIONS ON THE RELATIONS OF THE BASES OF POTASH AND SODA TO OTHER BODIES.

Should the bases of potash and soda be called metals? The greater number of philosophical persons to whom this question has been put, have answered in the affirmative. They agree with metals in opacity, lustre, malleability, conducting powers as to heat and electricity, and in their qualities of chemical combination.

Their low specific gravity does not appear a sufficient reason for making them a new class; for amongst the metals themselves there are remarkable differences in

* Researches Chem. and Phil. p. 287.

this respect, platina being nearly four times as heavy as tellurium;* and in the philosophical division of the classes of bodies, the analogy between the greater number of properties must always be the foundation of arrangement.

On this idea, in naming the bases of potash and soda, it will be proper to adopt the termination which, by common consent, has been applied to other newly discovered metals, and which, though originally Latin, is now naturalized in our language.

Ptoassium and sodium are the names by which I have ventured to call the two new substances; and whatever changes of theory, with regard to the composition of bodies, may hereafter take place, these terms can scarcely express an error; for they may be considered as implying simply the metals produced from potash and soda. I have consulted with many of the most eminent scientific persons in this country upon the methods of derivation, and the one I have adopted has been the one most generally approved. It is perhaps more significant than elegant. But it was not possible to found names upon specific properties not common to both; and though a name for the basis of soda might have been borrowed from the Greek, yet an analagous one could not have been applied to that of potash, for the ancients do not seem to have distinguished between the two alkalies.

The more caution is necessary in avoiding any theoretical expression in the terms, because the new electro-chemical phenomena that are daily becoming disclosed, seem distinctly to show that the mature time for a complete generalization of chemical facts is yet far distant; and though, in the explanations of the various results of experiments that have been detailed, the antiphlogistic solution of the phenomena has been uniformly adopted, yet the motive for employing it has been rather a sense of its beauty and precision, than a conviction of its permanency and truth.

The discovery of the agencies of the gases destroyed the hypothesis of Stahl. The knowledge of the powers and effects of the etherial substances may at a future time possibly act a similar part with regard to the more refined and ingenious hypothesis of Lavoisier; but, in the present state of our knowledge, it appears the best approximation that has been made to a perfect logic of chemistry.

Whatever future changes may take place in theory, there seems however every reason to believe that the metallic bases of the alkalies, and the common metals, will stand in the same arrangement of substances; and as yet we have no good reasons for assuming the compound nature of this class of bodies.†

The experiments in which it is said that alkalies, metallic oxides, and earths may be formed from air and water alone, in processes of vegetation, have been always made in an inconclusive manner;‡ for distilled water, as I have endea-

* Tellurium is not much more than six times as heavy as the basis of soda. There is great reason to believe that bodies of a similar chemical nature to the bases of potash and soda will be found of intermediate specific gravities between them and the lightest of the common metals. Of this subject, I shall treat again in the text in some of the following pages.

† A phlogistic chemical theory might certainly be defended, on the idea that the metals are compounds of certain unknown bases with the same matter as that existing in hydrogen; and the metallic oxides, alkalies and acids, compounds of the same bases with water;—but in this theory more unknown principles would be assumed than in the generally received theory. It would be less elegant and less distinct. In my first experiments on the distillation of the basis of potash, finding hydrogen generally produced, I was led to compare the phlogistic hypothesis with the new facts, and I found it fully adequate to the explanation. More delicate researches, however, afterwards proved that in the cases when inflammable gases appeared, water, or some body in which hydrogen is admitted to exist, was present.

‡ The explanation of Van Helmont of his fact of the production of earth in the growth of the willow, was completely overturned by the researches of Woodward. Phil. Trans. vol. xxi. p. 193.

The conclusions which M. Braconnot has very lately drawn from his ingenious experiments, Annales de Chimie, Fevrier 1807, page 187, are rendered of little avail in consequence of the circumstances stated in the text. In the only case of vegetation in which the free atmosphere was excluded, the seeds grew in white sand, which is stated to have been purified by washing in muriatic acid; but such a process was insufficient to deprive it of substances which might afford carbon, or various inflammable matters. Carbonaceous matter exists in several stones which afford a whitish or greyish powder; and

voured to show,* may contain both saline and metallic impregnations; and the free atmosphere almost constantly holds in mechanical suspension solid substances of various kinds.

In the common processes of nature, all the products of living beings may be easily conceived to be elicited from known combinations of matter. The compounds of iron, of the alkalies, and earths, with mineral acids, generally abound in soils. From the decomposition of basaltic, porphyritic, and granitic rocks, there is a constant supply of earthy, alkaline, and ferruginous materials to the surface of the earth. In the sap of all plants that have been examined, certain neutrosaline compounds, containing potash, or soda, or iron, have been found. From plants they may be supplied to animals. And the chemical tendency of organization seems to be rather to combine substances into more complicated and diversified arrangements, than to reduce them into simple elements.

VIII.—ON THE NATURE OF AMMONIA AND ALKALINE BODIES IN GENERAL; WITH OBSERVATIONS ON SOME PROSPECTS OF DISCOVERY OFFERED BY THE PRECEDING FACTS.

Ammonia is a substance, the chemical composition of which has always been considered of late years as most perfectly ascertained, and the apparent conversion of it into hydrogen and nitrogen, in the experiments of Scheele, Priestley, and the more refined and accurate experiments of Berthollet, had left no doubt of its nature in the minds of the most enlightened chemists.

All new facts must be accompanied however by a train of analogies, and often by suspicions with regard to the accuracy of former conclusions. As the two fixed alkalies contain a small quantity of oxygen united to peculiar bases, may not the volatile alkali likewise contain it? was a query which soon occurred to me in the course of inquiry; and in perusing the accounts of the various experiments made on the subject, some of which I had carefully repeated, I saw no reason to consider the circumstance as impossible. For supposing hydrogen and nitrogen to exist in combination with oxygen in low proportion, this last principle might easily disappear in the analytical experiments of decomposition by heat and electricity, in water deposited upon the vessels employed or dissolved in the gases produced.

Of the existence of oxygen in volatile alkali I soon satisfied myself. When charcoal carefully burned and freed from moisture was ignited by the Voltaic battery of the power of 250 of 6 and 4 inches square, in a small quantity of very pure ammoniacal gas:‡ a great expansion of the aeriform matter took place, and a white substance formed, which collected on the sides of the glass tube employed in the process; and this matter, exposed to the action of diluted muriatic acid, effervesced, so that it was probably carbonate of ammonia.

A process of another kind offered still more decisive results. In this the two

when in a stone, the quantity of carbonate of lime is very small in proportion to the other earthy ingredients, it is scarcely acted on by acids.

* Bakerian Lecture, 1806, page 4.

† In the year 1804, for a particular purpose of geological inquiry, I made an analysis of the porcelain clay of St. Stevens, in Cornwall, which results from the decomposition of the feldspar of fine-grained granite. I could not detect in it the smallest quantity of alkali. In making some experiments on specimens of the undecompounded rock taken from beneath the surface, there were evident indications of the presence of a fixed alkali, which seemed to be potash. So that it is very probable that the decomposition depends on the operation of water and the carbonic acid of the atmosphere on the alkali forming a constituent part of the crystalline matter of the feldspar, which may disintegrate from being deprived of it.

‡ The apparatus in which this experiment was made is described in page 214, Journal of the Royal Institution. The gas was confined by mercury which had been previously boiled to expel any moisture that might adhere to it. The ammonia had been exposed to the action of dry pure potash, and a portion of it equal in volume to 10980 grains of mercury, when acted on by distilled water, left a residuum equal to 9 grains of mercury only. So that the gas, there is every reason to believe, contained no foreign aëriform matter; for even the minute residuum may be accounted for by supposing it derived from air dissolved in the water.

mercurial gasometers of the invention of Mr. Pepys, described in No. xiv. of the Phil. Trans. for 1807, were used with the same apparatus, as that employed by Messrs. Allen and Pepys for the combustion of the diamond, and these gentlemen kindly assisted in the experiment.

Very pure ammoniacal gas was passed over iron wire ignited in a platina tube, and two curved glass tubes were so arranged as to be inserted into a freezing mixture; and through one of these tubes the gas entered into the platina tube, and through the other, it passed from the platina tube into the airholder arranged for its reception.

The temperature of the atmosphere was 55°; but it was observed that no sensible quantity of water was deposited in the cooled glass tube transmitting the unaltered ammonia, but in that receiving it after its exposure to heat, moisture was very distinct, and the gas appeared in the airholder densely clouded.

This circumstance seems distinctly to prove the formation of water in this operation for the decomposition of ammonia; unless indeed it be asserted that the hydrogen and nitrogen gases evolved hold less water in solution or suspension than the ammonia decomposed, an idea strongly opposed by the conclusions of Mr. Dalton,* and the experiments of Messrs. Desormes and Clement.†

After the gas had been passed several times through the ignited tube from one gasometer to the other, the results were examined. The iron wire became converted superficially into oxide, and had gained in weight 44-100th parts of a grain, about 4-10ths of a grain of water were collected from the cooled glass tubes by means of filtrating paper, and 33·8 cubic inches of gas were expanded into 55·3 cubic inches, and by detonation with oxygen it was found that the hydrogen gas in these was to the nitrogen as 3·2 to 1 in volume.

It will be useless to enter into the more minute details of this experiment, as no perfectly accurate data for proportions can be gained from them; for the whole of the ammonia was not decomposed, and as the gas had been prepared by being sent from a heated mixture of salammoniac and quicklime, into the airholder, it was possible that some solution of ammonia might have been deposited, which, by giving out new gas during the operation, would increase the absolute quantity of the material acted upon.

In examining the results of M. Berthollet's‡ elaborate experiments on the decomposition of ammonia by electricity, I was surprised to find that the weight of the hydrogen and nitrogen produced, rather exceeded than fell short of that of the ammonia considered as decomposed, which was evidently contradictory to the idea of its containing oxygen. This circumstance, as well as the want of coincidence between the results and those of Priestley and Van Marum on the same subject, induced me to repeat the process of the electrization of ammonia, and I soon found that the quantities of the products in their relations to the apparent quantity of gas destroyed were influenced by many different causes.

Ammonia procured over dry mercury from a mixture of dry lime and muriate of ammonia, I found deposited moisture upon the sides of the vessel in which it was collected, and in passing the gas into the tube for electrization, it was not easy to avoid introducing some of this moisture, which must have been a saturated solution of ammonia, at the same time.

In my first trials made upon gas, passed immediately from the vessel in which it had been collected into the apparatus, I found the expansion of 1 of ammonia vary in different instances from 2·8 to 2·2 measures, but the proportions of the nitrogen and hydrogen appeared uniform, as determined by detonation of the mixed gas with oxygen, and nearly as 1 to 3 in volume.

To exclude free moisture entirely, I carefully prepared ammonia in a mercurial airholder, and after it had been some hours at rest, passed a quantity of it into the tube for decomposition, which had been filled with dry mercury. In this case 50 parts become 103 parts by electrization, and there was still reason to suspect sources of error.

I had used iron wires not perfectly free from rust, for taking the spark, and a black film from the mercury appeared on the sides of the tube. It was probable

* Manchester Memoirs, vol. v. part ii. p. 535. 1785.
† Annales de Chimie, vol. xlii. p. 125.
‡ Mémoires de l'Academie, 1782. p. 324.

that some ammonia had been absorbed by the metallic oxides both upon the iron and the mercury, which might again have been given out in the progress of the operation.

I now used recently distilled mercury, which did not leave the slightest film on the glass tube, and wires of platina. The ammonia had been exposed to dry caustic potash, and proved to be equally pure with that mentioned in page 37. 60 measures of it, each equal to a grain of water, were electrized till no farther expansion could be produced, the gas filled a space equal to that occupied by 108 grains of water. The thermometer in this experiment was at 56° and the barometer at 30·1 inches. The wire of platina transmitting the spark was slightly tarnished.* The 108 measures of gas carefully analyzed, were found to consist of 80 measures in volume of hydrogen, and 28 measures of nitrogen.

The results of an experiment that I made in 1799,† give the weight of 100 cubic inches of ammonia, as 18·18 grains at the mean temperature and pressure. I had reasons however for suspecting that this estimation might be somewhat too low, and on mentioning the circumstance to Messrs. Allen and Pepys, they kindly undertook the examination of the subject, and Mr. Allen soon furnished me with the following data:—"In the first experiment 21 cubic inches of ammonia weighed 4·05 grains; in a second experiment, the same quantity weighed 5·06 grains, barometer 30·65, thermometer 54° Fahrenheit."

Now, if the corrections for temperature and pressure be made for these estimations, and a mean taken, 100 cubic inches of ammonia will weigh 18·67 grains, barometer being at 30, and thermometer at 60° Fahrenheit; and if the quantity used in the experiment of decomposition be calculated upon as cubic inches, 60 will weigh 11·2 grains. But the hydrogen gas evolved equal to 80 will weigh 1·93‡ grains, and the nitrogen equal to 28§ will weigh 8·3. And 11·2 grains— 1·9 + 8·3 = 10·2, and 11·2 — 10·2. = 1, all the estimations being made according to the standard temperature and pressure.

So that in this experiment on the decomposition of ammonia, the weight of the gases evolved is less by nearly one-eleventh than that of the ammonia employed; and this loss can only be ascribed to the existence of oxygen in the alkali; part of which probably combined with the platina wires employed for electrization, and part with hydrogen.

After these ideas the oxygen in ammonia cannot well be estimated at less than 7 or 8 parts in the hundred; and it possibly exists in a larger proportion, as the gases evolved may contain more water than the gas decomposed, which of course would increase their volume and their absolute weight.‖

In supposing ammonia a triple compound of nitrogen, hydrogen, and oxygen, it is no less easy to give a rational account of the phenomena of its production and decomposition, than in adopting the generally received hypothesis of its composition.

Oxygen, hydrogen, and nitrogen, are always present in cases in which volatile alkali is formed; and it usually appears during the decomposition of bodies in which oxygen is loosely attached, as in that of the compounds of oxygen and nitrogen dissolved in water.

At common temperatures under favourable circumstances, the three elements may be conceived capable of combining and of remaining in union; but at the heat of ignition the affinity of hydrogen for oxygen prevails over the complex attraction, water is formed, and hydrogen and nitrogen are evolved; and accord-

* This most probably was owing to oxidation. When platina is made positive in the Voltaic circuit in contact with solution of ammonia, it is rapidly corroded; this is an analogous instance.

† Researches Chem. and Phil. p. 62.

‡ Lavoisier's Elements, p. 569. A cubical inch of hydrogen is considered as weighing ·0239.

§ Researches Chem. and Phil. p. 9. From my experiments 100 cubical inches of nitrogen weigh at the standard temperature and pressure 29·6 grains.

‖ In the present state of our knowledge, perfectly correct data for proportions cannot probably be gained in any experiments on the decomposition of ammonia, as it seems impossible to ascertain the absolute quantity of water in this gas, for electrization, according to Dr. Henry's ingenious researches, offers the only means known of ascertaining the quantity of water in gases.

ing to these conclusions, ammonia will bear the same relations to the fixed alkalies, as the vegetable acids with compound bases do to the mineral ones with simple bases.

Oxygen then may be considered as existing in, and as forming, an element in all the true alkalies; and the principle of acidity of the French nomenclature, might now likewise be called the principle of alkalescence.

From analogy alone it is reasonable to expect that the alkaline earths are compounds of a similar nature to the fixed alkalies, peculiar highly combustible metallic bases united to oxygen. I have tried some experiments upon barytes and strontites; and they go far towards proving that this must be the case. When barytes and strontites, moistened with water, were acted upon by the power of the battery of 250 of 4 and 6, there was a vivid action and a brilliant light at both points of communication, and an inflammation at the negative point.

In these cases the water might possibly have interfered. Other experiments gave however more distinct results.

Barytes and strontites, even when heated to intense whiteness in the electrical circuit, by a flame supported by oxygen gas, are non-conductors; but, by means of combination with a very small quantity of boracic acid, they become conductors; and in this case inflammable matter, which burns with a deep red light in each instance, is produced from them at the negative surface. The high temperature has prevented the success of attempts to collect this substance; but there is much reason to believe that it is the basis of the alkaline earth employed.

Barytes and strontites have the strongest relations to the fixed alkalies of any of the earthy bodies;* but there is a chain of resemblances, through lime, magnesia, glucina, alumina, and silex. And by the agencies of batteries sufficiently strong, and by the application of proper circumstances, there is no small reason to hope, that even these refractory bodies will yield their elements to the methods of analysis by electrical attraction and repulsion.

In the electrical circuit we have a regular series of powers of decomposition, from an intensity of action so feeble as scarcely to destroy the weakest affinity existing between the parts of a saline neutral compound, to one sufficiently energetic to separate elements of the strongest degree of union, in bodies undecomposable under other circumstances.

When the powers are feeble, acids and alkalies, and acids and metallic oxides, merely separate from each other; when they are increased to a certain degree, the common metallic oxides and the compound acids are decomposed; and by means still more exalted, the alkalies yield their elements. And as far as our knowledge of the composition of bodies extends, all substances attracted by positive electricity, are oxygen, or such as contain oxygen in excess; and all that are attracted by negative electricity, are pure combustibles, or such as consist chiefly of combustible matter.

The idea of muriatic acid, fluoric acid, and boracic acid containing oxygen, is highly strengthened by these facts. And the general principle confirms the conjecture just stated concerning the nature of the earths.

In the electrization of boracic acid moistened with water, I find that a dark coloured combustible matter is evolved at the negative surface; but the researches upon the alkalies have prevented me from pursuing this fact, which seems, however, to indicate a decomposition.

Muriatic acid and fluoric acid in their gaseous state are non-conductors: and as there is every reason to believe that their bases have a stronger attraction for oxygen than water, there can be little hope of decomposing them in their aqueous solutions, even by the highest powers. In the electrization of some of their combinations there is however a probability of success.

* The similarity between the properties of earths and metallic oxides was noticed in the early periods of chemistry. The poisonous nature of barytes, and the great specific gravity of this substance as well as of strontites, led Lavoisier to the conjecture that they were of a metallic nature. That metals existed in the fixed alkalies seems, however, never to have been suspected. From their analogy to ammonia, nitrogen and hydrogen have been supposed to be amongst their elements. It is singular, with regard to this class of bodies, that those most unlike metallic oxides are the first which have been demonstrated to be such.

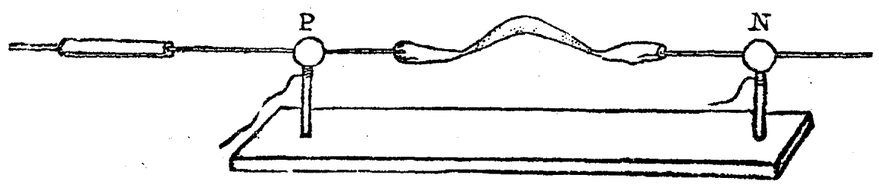
An immense variety of objects of research is presented in the powers and affinities of the new metals produced from the alkalies.

In themselves they will undoubtedly prove powerful agents for analysis; and having an affinity for oxygen stronger than any other known substances, they may possibly supersede the application of electricity to some of the undecompounded bodies.

The basis of potash I find oxidates in carbonic acid, and decomposes it, and produces charcoal when heated in contact with carbonate of lime. It likewise oxidates in muriatic acid; but I have had no opportunity of making the experiment with sufficient precision to ascertain the results.

In sciences kindred to chemistry, the knowledge of the nature of the alkalies, and the analogies arising in consequence, will open many new views; they may lead to the solution of many problems in geology, and show that agents may have operated in the formation of rocks and earths which have not hitherto been suspected to exist.

It would be easy to pursue the speculative part of this inquiry to a great extent, but I shall refrain from so occupying the time of the Society, as the tenor of my object in this lecture has not been to state hypotheses, but to bring forward a new series of facts.



III.

ELECTRO-CHEMICAL RESEARCHES ON THE DECOMPOSITION OF THE EARTHS; WITH OBSERVATIONS ON THE METALS OBTAINED FROM THE ALKALINE EARTHS, AND ON THE AMALGAM PROCURED FROM AMMONIA.

Read before the Royal Society, June 30, 1808.

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I.—INTRODUCTION.

IN the Philosophical Transactions for 1807, Part I. and 1808, Part I.* I have detailed the general methods of decomposition by electricity, and stated various new facts obtained in consequence of the application of them.

The results of the experiments on potash and soda, as I stated in my last communication to the Society, afforded me the strongest hopes of being able to effect the decomposition both of the alkaline and common earths; and the phenomena obtained in the first imperfect trials made upon those bodies countenanced the ideas that had obtained from the earliest periods of chemistry, of their being metallic in their nature.†

Many difficulties, however, occurred in the way of obtaining complete evidence on this subject: and the pursuit of the inquiry has required much labour and a considerable devotion of time, and has demanded more refined and complicated processes than those which had succeeded with the fixed alkalies.

* See pages 1 and 23, of this edition.

† Beccher is the first chemist, as far as my reading informs me, who distinctly pointed out the relations of metals to earthy substances. See Phys. subt. Lipsiæ, 4to. p. 61. He was followed by Stahl, who has given the doctrine a more perfect form. Beccher's idea was that of an universal elementary earth, which, by uniting to an inflammable earth, produced all the metals, and under other modifications formed stones. Stahl admitted distinct earths which he supposed might be converted into metals by combining with phlogiston; see Stahl Fundament. Chym. p. 9. 4to. and Conspect. Chem. 1. 77. 4to.—Neuman gives an account of an elaborate series of unsuccessful experiments which he made to obtain a metal from quicklime. Lewis's Neuman's Chem. Works, 2d edit. vol. i. p. 15. The earlier English chemical philosophers seem to have adopted the opinion of the possibility of the production of metals from common earthy substances; see Boyle, vol. i. 4to. p. 564, and Grew, Anatomy of Plants, lec. ii. p. 242. But these notions were founded upon a kind of alchemical hypothesis of a general power in nature of transmuting one species of matter into another. Towards the end of the last century the doctrine was advanced in a more philosophical form; Bergman suspected barytes to be a metallic calx, Præf. Sciagrap. Reg. Min. and Opusc. iv. 212. Baron supported the idea of the probability of alumine being a metallic substance, see Annales de Chimie, vol. x. p. 257.—Lavoisier extended these notions, by supposing the other earths metallic oxides. Elements, 2d edit. Kerr's translation, p. 217. The general inquiry was closed by the assertion of Tondi and Ruprecht, that the earths might be reduced by charcoal; and the accurate researches of Klaproth and Săvaresi, who proved by the most decisive experiments, that the metals taken for the bases of the earths were phosphurets of iron, obtained from the bone ashes and other materials employed in the experiment, Annales de Chimie, vol viii. p. 18, and vol. x. p. 257—275. Amidst all these hypotheses, potash and soda were never considered as metallic in their nature; Lavoisier supposed them to contain azote; nor at that time were there any analogies to lead that acute philosopher to a happier conjecture.

The earths like the fixed alkalies are non-conductors of electricity; but the fixed alkalies become conducting by fusion: the infusible nature of the earths, however, rendered it impossible to operate upon them in this state: the strong affinity of their bases for oxygen, made it unavailing to act upon them in solution in water; and the only methods that proved successful, were those of operating upon them by electricity in some of their combinations, or of combining them at the moment of their decomposition by electricity, in metallic alloys, so as to obtain evidences of their nature and properties.

I delayed for some time laying an account of many of the principal results which I obtained before the Society, in the hopes of being able to render them more distinct and satisfactory; but finding that for this end a more powerful battery, and more perfect apparatus than I have a prospect of seeing very soon constructed, will be required, I have ventured to bring forward the investigation in its present imperfect state; and I shall prefer the imputation of having published unfinished labours, to that of having concealed any new facts from the scientific world, which may tend to assist the progress of chemical knowledge.

II.—METHODS EMPLOYED FOR DECOMPOSING THE ALKALINE EARTHS.

Barytes, strontites, and lime, slightly moistened, were electrified by iron wires under naphtha, by the same methods, and with the same powers as those employed for the decomposition* of the fixed alkalies. In these cases, gas was copiously evolved, which was inflammable; and the earths where in contact with the negative metallic wires became dark coloured, and exhibited small points having a metallic lustre, which, when exposed to air, gradually became white; they became white likewise when plunged under water, and when examined in this experiment by a magnifier, a greenish powder seemed to separate from them, and small globules of gas were disengaged.

In these cases there was great reason to believe that the earths had been decomposed; and that their bases had combined with the iron, so as to form alloys decomposable by the oxygen of air or water; but the indistinctness of the effect, and the complicated circumstances required for it, were such as to compel me to form other plans of operation.

The strong attraction of potassium for oxygen, induced me to try whether this body might not detach the oxygen from the earths, in the same manner as charcoal decomposes the common metallic oxides.

I heated potassium in contact with dry pure lime, barytes, strontites, and magnesia in tubes of plate glass; but as I was obliged to use very small quantities, and as I could not raise the heat to ignition without fusing the glass, I obtained in this way no good results. The potassium appeared to act upon the earths and on the glass, and dark brown substances were obtained, which evolved gas from water; but no distinct metallic globules could be procured: from these circumstances, and other like circumstances, it seemed probable, that though potassium may partially deoxigenate the earths, yet its affinity for oxygen, at least at the temperature which I employed, is not sufficient to effect their decomposition.

I made mixtures of dry potash in excess, and dry barytes, lime, strontites, and magnesia, brought them into fusion, and acted upon them in the Voltaic circuit in the same manner as that I employed for obtaining the metals of the alkalies. My hopes were, that the potassium, and the metals of the earths might be deoxigenated at the same time, and enter into combination in alloy.

In this way of operating, the results were more distinct than in the last: metallic substances appeared less fusible than potassium, which burned the instant after they had formed, and which by burning produced a mixture of potash and the earth employed; I endeavoured to form them under naphtha, but without much success. To produce the result at all, required a charge by the action of nitric acid, which the state of the batteries did not permit me often to employ;† and the metal was generated only in very minute films, which could not be detached by fusion, and which were instantly destroyed by exposure to air.

I had found in my researches upon potassium, that when a mixture of potash

* See page 24.

† The power of this combination, though it consisted of one hundred plates of copper

and the oxides of mercury, tin, or lead, was electrified in the Voltaic circuit, the decomposition was very rapid, and an amalgam, or an alloy of potassium was obtained; the attraction between the common metals and the potassium apparently accelerating the separation of the oxygen.

The idea that a similar kind of action might assist the decomposition of the alkaline earths, induced me to electrify mixtures of these bodies and the oxide of tin, of iron, of lead, of silver, and of mercury; and these operations were far more satisfactory than any of the others.

A mixture of two-thirds of barytes and one-third of oxide of silver very slightly moistened was electrified by iron wires; an effervescence took place at both points of contact, and a minute quantity of a substance, possessing the whiteness of silver, formed at the negative point. When the iron wire to which this substance adhered was plunged into water containing a little alum in solution, gas was disengaged, which proved to be hydrogen; and white clouds which were found to be sulphate of barytes, descended from the point of the wire.

A mixture of barytes and red oxide of mercury, in the same proportions, was electrified in the same manner. A small mass of solid amalgam adhered to the negative wire, which evidently contained a substance, that produced barytes by exposure to air, with the absorption of oxygen; and which occasioned the evolution of hydrogen from water, leaving pure mercury, and producing a solution of barytes.

Mixtures of lime, strontites, magnesia, and red oxide of mercury, treated in the same manner, gave similar amalgams, from which the alkaline earths were regenerated by the action of air or water, with like phenomena; but the quantities of metallic substances obtained were exceedingly minute; they appeared as mere superficial formations surrounding the point of the wire, nor did they increase after the first few minutes of electrization, even when the process was carried on for some hours.

These experiments were made previous to April, 1808, at which time the batteries were so much injured by constant use, as no longer to form an efficient combination. The inquiry was suspended for a short time; but in May I was enabled to resume it, by employing a new and much more powerful combination, constructed in the Laboratory of the Royal Institution, and consisting of five hundred pairs of double plates of six inches square.

When I attempted to obtain amalgams with this apparatus, the transmitting wires being of platina, of about one-fortieth of an inch in diameter; the heat generated was so great as to burn both the mercury and basis of the amalgam at the moment of its formation; and when, by extending the surfaces of the conductors, this power of ignition was modified, yet still the amalgam was only produced in thin films, and I could not obtain globules sufficiently large to submit to distillation. When the transmitting wires were of iron of the same thickness, the iron acquired the temperature of ignition, and combined with the bases of the earths in preference to the mercury, and metallic alloys of a dark grey colour were obtained, which acted on water with the evolution of hydrogen, and were converted into oxide of iron, and alkaline earths.

Whilst I was engaged in these experiments, in the beginning of June, I received a letter from Professor Berzelius of Stockholm, in which he informed me that in conjunction with Dr. Pontin, he had succeeded in decomposing barytes and lime, by negatively electrifying mercury in contact with them, and that in this way he had obtained amalgams of the metals of these earths.

I immediately repeated these operations with perfect success; a globule of

and zinc of six inches, and one hundred and fifty of four inches, at this time was not more than equal to that of a newly constructed apparatus of one hundred and fifty, of four inches. It had been made for the demonstrations in the Theatre of the Royal Institution in 1803; and since that time had been constantly employed in the annual courses of Lectures, and had served in different parts, for the numerous experiments on the decomposition of bodies by electricity, detailed in the Bakerian Lectures for 1806 and 1807, and a number of the plates were destroyed by corrosion. I mention these circumstances, because many chemists have been deterred from pursuing experiments on the decomposition of the alkalies and the earths, under the idea that a very powerful combination was required for the effect. This, however, is far from being the case; all the experiments detailed in the text may be repeated by means of a Voltaic battery, contained from one hundred to one hundred and fifty plates of four or six inches.

mercury, electrified by the power of the battery of 500, weakly charged, was made to act upon a surface of slightly moistened barytes, fixed upon a plate of platina. The mercury gradually became less fluid, and after a few minutes was found covered with a white film of barytes; and when the amalgam was thrown into water, hydrogen was disengaged, the mercury remained free, and a solution of barytes was formed.

The result with lime, as these gentlemen had stated, was precisely analogous.

That the same happy methods must succeed with strontites and magnesia, it was not easy to doubt, and I quickly tried the experiment.

From strontites I obtained a very rapid result; but from magnesia, in the first trials, no amalgam could be procured. By continuing the process, however, for a longer time, and keeping the earth continually moist, at last a combination of the basis with mercury was obtained, which slowly produced magnesia by absorption of oxygen from air, or by the action of water.

All these amalgams I found might be preserved for a considerable period under naphtha. In a length of time, however, they became covered with a white crust under this fluid. When exposed to air, a very few minutes only were required for the oxigenation of the bases of the earths. In water the amalgam of barytes was most rapidly decomposed: that of strontites and that of lime next in order: but the amalgam from magnesia, as might be expected from the weak affinity of the earth for water, very slowly changed; when a little sulphuric acid was added to the water, however, the evolution of hydrogen, and the production and solution of magnesia were exceedingly rapid, and the mercury soon remained free.

I was inclined to believe that one reason why magnesia was less easy to metallize than the other alkaline earths, was its insolubility in water, which would prevent it from being presented in the nascent state, detached from its solution at the negative surface. On this idea I tried the experiment, using moistened sulphate of magnesia, instead of the pure earth; and I found that the amalgam was much sooner obtained. Here the magnesia was attracted from the sulphuric acid, and probably deoxigenated and combined with the quicksilver at the same instant.

The amalgams of the other bases of the alkaline earths could, I found, be obtained in the same manner from their saline compounds.

I tried in this way very successfully, muriate and sulphate of lime, the muriate of strontites and of barytes, and nitrate of barytes. The earths separated at the deoxigenating surface, there seemed instantly to undergo decomposition, and seized upon by the mercury, were in some measure defended from the action of air, and from the contact of water, and preserved by their strong attraction for this metal.

III.—ATTEMPTS TO PROCURE THE METALS OF THE ALKALINE EARTHS; AND ON THEIR PROPERTIES.

To procure quantities of amalgams sufficient for distillation, I combined the methods I had before employed, with those of MM. Berzelius and Pontin.

The earths were slightly moistened, and mixed with one-third of red oxide of mercury, the mixture was placed on a plate of platina, a cavity was made in the upper part of it to receive a globule of mercury, of from 50 to 60 grains in weight, the whole was covered by a film of naphtha, and the plate was made positive, and the mercury negative by a proper communication with the battery of 500.

The amalgams obtained in this way were distilled in tubes of plate glass, or in some cases in tubes of common glass. These tubes were bent in the middle, and the extremities were enlarged, and rendered globular by blowing, so as to serve the purposes of a retort and receiver.

The tube, after the amalgam had been introduced, was filled with naphtha, which was afterwards expelled by boiling, through a small orifice in the end corresponding to the receiver, which was hermetically sealed when the tube contained nothing but the vapour of naphtha, and the amalgam.

I found immediately that the mercury rose pure by distillation from the amalgam, and it was very easy to separate a part of it; but to obtain a complete decomposition was very difficult.

For this nearly a red heat was required, and at a red heat the bases of the earths instantly acted upon the glass, and became oxigenated. When the tube was large in proportion to the quantity of amalgam, the vapour of the naphtha furnished oxygen sufficient to destroy part of the bases: and when a small tube was employed, it was difficult to heat the part used as a retort sufficient to drive off the whole of the mercury from the basis, without raising too highly the temperature of the part serving for the receiver, so as to burst the tube.*

In consequence of these difficulties, in a multitude of trials, I obtained only a very few successful results, and in no case could I be absolutely certain that there was not a minute portion of mercury still in combination with the metals of the earths.

In the best result that I obtained from the distillation of the amalgam of barytes, the residuum appeared as a white metal of the colour of silver. It was fixed at all common temperatures, but became fluid at a heat below redness, and did not rise in vapour when heated to redness, in a tube of plate glass, but acted violently upon the glass, producing a black mass, which seemed to contain barytes, and a fixed alkaline basis, in the first degree of oxigenation.†

* When the quantity of the amalgam was about fifty or sixty grains, I found that the tube could not be conveniently less than one-sixth of an inch in diameter, and of the capacity of about half a cubic inch.

† From this fact, compared with other facts that have been stated, p. 42, it may be conjectured, that the basis of barytes has a higher affinity for oxygen than sodium; and hence, probably the bases of the earths will be more powerful instruments for detecting oxygen, than the bases of the alkalies.

I have tried a number of experiments on the action of potassium on bodies supposed simple, and on the undecompounded acids. From the affinity of the metal for oxygen, and on the acid for the substance formed, I had entertained the greatest hopes of success. It would be inconsistent with the object of this paper to enter into a full detail of the methods of operation; I hope to be able to state them fully to the Society at a future time, when they shall be elucidated by further researches; I shall now merely mention the general results, to show that I have not been tardy in employing the means which were in my power, towards effecting these important objects.

When potassium was heated in muriatic acid gas, as dry as it could be obtained by common chemical means, there was a violent chemical action with ignition; and when the potassium was in sufficient quantity, the muriatic acid gas wholly disappeared, and from one-third to one-fourth of its volume of hydrogen was evolved, and muriate of potash was formed.

On fluoric acid gas, which had been in contact with glass, the potassium produced a similar effect; but the quantity of hydrogen generated was only one-sixth or one-seventh of the volume of gas, and a white mass was formed, which principally consisted of fluate of potash and silex, but which emitted fumes of fluoric acid when exposed to air.

When boracic acid, prepared in the usual manner, that had been ignited, was heated in a gold tube with potassium, a very minute quantity of gas only was liberated, which was hydrogen, mixed with nitrogen, (the last probably from the common air in the tube); borate of potash was formed, and a black substance, which became white by exposure to air.

In all these instances there is great reason to believe that the hydrogen was produced from the water adhering to the acids; and the different proportions of it in the different cases, are a strong proof of this opinion. Admitting this idea, it seems that muriatic acid gas must contain at least one-eighth or one-tenth of its weight of water; and that the water oxigenates in the experiment a quantity of potassium, sufficient to absorb the whole of the acid.

In the cases of fluoric and boracic acids, there is probably a decomposition of these bodies; the black substance produced from the boracic acid is similar to that which I had obtained from it by electricity. The quantities that I have operated upon, have been as yet too small to enable me to separate and examine the products, and till this is done, no ultimate conclusion can be drawn.

The action of potassium upon muriatic acid gas, indicates a much larger quantity of water in this substance, than the action of electricity in Dr. Henry's elaborate experiments; but in the one instance the acid enters into a solid salt, and in the other it remains aëriform; and the difficulty of decomposition by electricity, must increase in proportion as the quantity of water diminishes, so that at the apparent maximum of electrical effect, there is no reason to suppose the gas free from water.

Those persons who have supposed hydrogen to be the basis of muriatic acid may, perhaps, give another solution of the phenomena, and consider the experiment I have detailed as a proof of this opinion.

When exposed to air, it rapidly tarnished, and fell into a white powder, which was barytes. When this process was conducted in a small portion of air, the oxygen was found absorbed, and the nitrogen unaltered; when a portion of it was introduced into water, it acted upon it with great violence and sunk to the bottom, producing in it barytes; and hydrogen was generated. The quantities in which I obtained it were too minute for me to be able to examine correctly, either its physical or chemical properties. It sunk rapidly in the water, and even in sulphuric acid, though surrounded by globules of hydrogen, equal to two or three times its volume; from which it seems probable, that it cannot be less than four or five times as heavy as water. It flattened by pressure, but required a considerable force for this effect.

The metal from strontites sunk in sulphuric acid, and exhibited the same characters as that from barytes, except in producing strontites by oxidation.

The metal from lime, I have never been able to examine exposed to air or under naphtha. In the case in which I was able to distil the quicksilver from it to the greatest extent, the tube unfortunately broke, whilst warm, and at the moment that the air entered, the metal, which had the colour and lustre of silver, instantly took fire, and burned with an intense white light into quicklime.

The metal from magnesia seemed to act upon the glass, even before the whole of the quicksilver was distilled from it. In an experiment in which I stopped the process before the mercury was entirely driven off, it appeared as a solid, having the same whiteness and lustre as the other metals of the earths. It sunk rapidly in water, though surrounded by globules of gas, producing magnesia, and quickly changed in air, becoming covered with a white crust, and falling into a fine powder, which proved to be magnesia.

In several cases in which amalgams of the metals of the earths, containing only a small quantity of mercury were obtained, I exposed them to air on a delicate balance, and always found that during the conversion of metal into earth, there was a considerable increase of weight.

I endeavoured to ascertain the proportions of oxygen, and bases, in barytes and strontites, by heating amalgams of them in tubes filled with oxygen, but without success. I satisfied myself, however, that when the metals of the earths were burned in a small quantity of air they absorbed oxygen, gained weight in the process, and were in the highly caustic or unslacked state; for they produced strong heat by the contact of water, and did not effervesce during their solution in acids.

The evidence for the composition of the alkaline earths is then of the same kind as that for the composition of the common metallic oxides; and the principles of their decomposition are precisely similar, the inflammable matters in all cases separating at the negative surface in the Voltaic circuit, and the oxygen at the positive surface.

These new substances will demand names; and on the same principles as I have named the bases of the fixed alkalies, potassium and sodium, I shall venture to denominate the metals from the alkaline earths barium, strontium, calcium, and magnium; the last of these words is undoubtedly objectionable, but magnesium* has been already applied to metallic manganese, and would consequently have been an equivocal term.

IV.—INQUIRIES RELATIVE TO THE DECOMPOSITION OF ALUMINE, SILEX, ZIRCONE, AND GLUCINE.

I tried the methods of electrization and combination with quicksilver, and the common metals, by which I had succeeded in decomposing the alkaline earths, on alumine and silex, but without gaining distinct evidences of their having undergone any change in the processes.

Obliged to seek for other means of acting upon them, it was necessary to consider minutely their relations to other bodies, and to search for analogies by which the principles of research might be guided.

Alumine very slowly finds its point of rest at the negative pole, in the electrical circuit; but silex, even when diffused in its gelatinous state through water, rests indifferently at the negative or positive poles.

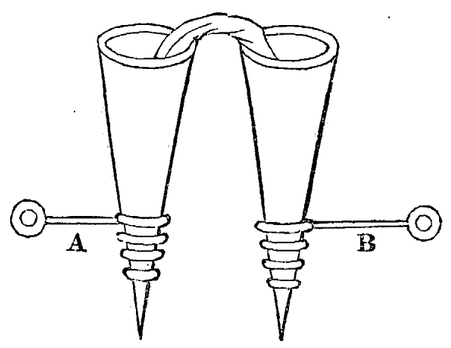
* Bergman, Opusc. tom. ii. p. 200.

From this indifference to positive and negative electrical attractions, following the general order of facts, it might be inferred, that if these bodies be compounds, the electrical energies of their elements are nearly in equilibrium; and that their state is either analogous to that of insoluble neutral salts, or of oxides nearly saturated with oxygen.

The combinations of silex and alumine, with acids and alkalies, as well as their electrical powers, were not inconsistent with either of these ideas; for in some respects they resemble in physical characters, fluate and phosphate of lime, as much as, in others, they approach to the oxides of zinc and tin.

On the idea that silex might be an insoluble neutrosaline compound, containing an unknown acid or earth, or both, and capable of being resolved into its secondary elements, in the same manner as sulphate of barytes, or fluate of lime, I made the following experiments.

Two gold cones, connected by moistened amianthus, were filled with pure water and placed in the electrical circuit, a small quantity of carefully prepared and well washed silex was introduced into the positive cone: the action was kept up from a battery of two hundred plates, for some hours, till nearly half of the fluid in each cone was exhausted; the remainders were examined; the fluid in the cone containing the silex was strongly acid; that in the opposite cone was strongly alkaline; the two fluids were passed through bibulous paper, and mixed together, when a precipitate fell down, which proved to be silex.



On the first view of the subject, it appeared probable that this silex had been formed by the union of the acid and the alkaline matter in the two cones, and that the experiment demonstrated a decomposition and recomposition of silex; but before such a conclusion could be made, many points were to be determined.

It was possible that the acid might be nitric acid, produced as in other electrical experiments of a similar nature, and that this acid might have dissolved silex, which was precipitated by the alkaline matter at the other pole, which might be either potash used for dissolving the silex, which had adhered to it, notwithstanding the processes of lixiviation in acids, or ammonia produced in consequence of the presence of the atmosphere; or if potash was present, it was likewise possible that the silex might have been carried over in solution, with this alkali, from the positive to the negative surface.

Minute experiments were instituted and completed in the same manner as those detailed in the Philosophical Transactions for 1807, p. 3, which soon proved that there was no reason to suppose that the silex had been changed in these experiments.

The acid proved to be nitric acid, which under the electrical action seemed to have dissolved the silex; the alkali turned out to be principally fixed alkali; and that it was merely an accidental ingredient, and not a constituent of the silex, appeared from this circumstance, that when the same portion of silex was long electrified, by degrees it lost its power of affording the substance in question.*

This result having taken place, the same plan of operation was not pursued with respect to alumine, which resembles a saline compound less than silex, and the method which I now adopted of acting upon these bodies, was on the supposition

* If silex that has been carefully washed, after precipitation by muriatic acid from liquor silicum, be moistened, and acted on by mercury negatively electrified, the mercury soon contains a notable quantity of potassium. Well washed alumine that has been precipitated from alum by carbonate of soda, affords by the same treatment sodium and potassium, so that the powers of electro-chemical analysis are continually demonstrating the imperfection of the common chemical methods of separating bodies from each other. The purest boracic acid which can be obtained from borax by chemical decomposition, by electrical analysis is shown to contain both soda, and the decomposing acid employed in the process; and hence the experiment on the action of the boracic acid and potassium, page 45, may possibly be explained without assuming its decomposition.

of their being inflammable substances so highly saturated with oxygen as to possess little or no positive electricity.

Alumine and silex have both a strong affinity for potash and soda. Now supposing them to be oxides, it was reasonable to conclude that the oxygen, both in the alkalies and the earths, must be passive as to this power, which must consequently be referred to their bases, and on this notion it was possible that it might be made to assist their decomposition by electricity.

After this reasoning, I fused a mixture of one part of silex, and six of potash in a platina crucible, and preserved the mixture fluid, and in ignition, over a fire of charcoal; the crucible was rendered positive from the battery of five hundred, and a rod of platina, rendered negative, was brought in contact with the alkaline menstruum. At the moment of contact there was a most intense light; when the rod was plunged into the liquid an effervescence took place, and globules which burnt with a brilliant flame rose to the surface, and swam upon it in a state of combustion. In a few minutes, when the mixture was cool, the platina bar was removed: after as much as possible of the alkali and silex had been detached from it by a knife, there remained brilliant metallic scales round it, which instantly became covered with a white crust in the air, and some of which inflamed spontaneously. The platina appeared much corroded, and of a darker tint than belongs to the pure metal. When it was plunged into water it strongly effervesced: the fluid that came from it was alkaline; when a few drops of muriatic acid were added to the solution, a white cloudiness occurred, which various trials demonstrated, depended upon the presence of silex.

A similar mixture of potash and alumine was experimented upon in the same manner, and the results were perfectly analogous; there adhered to the rod of platina a film of a metallic substance, which rapidly decomposed water, and afforded a solution which deposited alumine by the action of an acid.

I tried several forms of this experiment, with the hopes of being able to obtain a sufficient quantity of the metallic matter from the platina, so as to examine it in a separate state; but I was not successful. It was always in superficial scales, which oxidated, becoming white and alkaline, before it could be detached in the air; it instantly burnt when heated, and could not be fused under naphtha or oil.

I tried similar experiments with mixtures of soda and alumine, and soda and zircone, and used iron as the negatively electrified metal. In all these cases, during the whole process of electrization, abundance of globules, which swam in a state of inflammation on the fused mass, were produced. And in the mixture, when cooled, small laminæ of metal were found of the colour of lead, and less fusible than sodium, which adhered to the iron; they acted violently upon water, and produced soda and a white powder, but in quantities too small to be minutely examined.

I endeavoured to procure an alloy of potassium, and the bases of the earths, from mixtures of potash, silex, and alumine, fused by electricity, and acted on by the positive and negative surfaces in the same manner as pure potash, in experiments for the decomposition of that substance; but I obtained no good results. When the earths were in quantities equal to one-fourth or one-fifth of the alkali, they rendered it so highly non-conducting, that it was not easy to affect it by electricity, and when they were in very minute portions, the substance produced had the characters of pure potassium.

I heated small globules of potassium, in contact with silex and alumine, in tubes of plate glass filled with the vapour of naphtha: the potassium seemed to act at the same time upon the glass and the earths, and a grayish opaque mass, not possessed of metallic splendour was obtained, which effervesced in water, depositing white clouds. Here it was possible that the potash had been converted wholly or partly into protoxide, by its action upon the earths; but as no globule was obtained, and as the plate glass alone might have produced the effect, no decided inference of the decomposition of the earths can be drawn from the process.

I shall now mention the last trials that I made with respect to this object.

Potassium, amalgamated with about one-third of mercury, was electrified negatively under naphtha, in contact with silex very slightly moistened, by the power of five hundred; after an hour the result was examined. The potassium was made to decompose water, and the alkali formed neutralized by acetous acid;

a white matter, having all the appearance of silex precipitated, but in quantity too small for accurate examination.

I tried the same method of action upon alumine and glucine, and obtained a cloudiness, more distinct than in the case of silex, by the action of an acid upon the solution obtained from the amalgam.

Zircone exposed in the same manner to the action of electricity, and the attraction of potassium, furnished still more satisfactory results, for a white and fine powder, soluble in sulphuric acid, and which was precipitated from sulphuric acid by ammonia, separated from the amalgam that had been obtained, by the action of water.

From the general tenor of these results, and the comparison between the different series of experiments, there seems very great reason to conclude that alumine, zircone, glucine, and silex are, like the alkaline earths, metallic oxides, for on no other supposition is it easy to explain the phenomena that have been detailed.

The evidences of decomposition and composition, are not, however, of the same strict nature as those that belong to the fixed alkalies and alkaline earths; for it is possible, that in the experiments in which the silex, alumine, and zircone appeared to separate during the oxidation of potassium and sodium, their bases might not actually have been in combination with them, but the earths themselves, in union with the metals of the alkalies, or in mere mechanical mixture. And out of an immense number of experiments which I made of the kind last detailed, a very few only gave distinct indications of the production of any earthy matter; and in cases when earthy matter did appear, the quantity was such as rendered it impossible to decide on the species.

Had I been so fortunate as to have obtained more certain evidences on this subject, and to have procured the metallic substances I was in search of, I should have proposed for them the names of silicium, alumium, zirconium, and glucium.

V.—ON THE PRODUCTION OF AN AMALGAM FROM AMMONIA, AND ON ITS NATURE AND PROPERTIES.

In the communication from Professor Berzelius and Dr. Pontin, which I have already referred to, a most curious and important experiment on the deoxidation and amalgamation of the compound basis of ammonia is mentioned, which these ingenious gentlemen regard as a strict proof of the idea I had formed of its being an oxide with a binary basis.

Mercury, negatively electrified in the Voltaic circuit, is placed in contact with solution of ammonia. Under this agency it gradually increases in volume, and when expanded to four or five times its former dimensions, becomes a soft solid.

And that this substance is composed of the deoxigenated compound basis of ammonia and mercury, they think is proved; 1. By the reproduction of quicksilver and ammonia, with the absorption of oxygen, when it is exposed to air; and secondly, by its forming ammonia in water, whilst hydrogen is evolved, and the quicksilver gradually becomes free.

An operation, in which hydrogen and nitrogen exhibit metallic properties, or in which a metallic substance is apparently composed from its elements, cannot fail to fix the attention of chemists; and the peculiar interest which it offered in its relations to the general theory of electro-chemical science, induced me to examine the circumstances connected with it minutely and extensively.

In repeating the process of the Swedish chemists, I found that to form an amalgam from fifty or sixty grains of mercury, in contact with saturated solution of ammonia, required a considerable time, and that this amalgam greatly changed even in the short period required for removing it from the solution.

I was however able, in this mode of operating, to witness all the results they have stated, and I soon found simple and more easy means of producing the effect, and circumstances under which it could be more distinctly analyzed.

The experiments which I have detailed in the Bakerian Lecture for 1806, proved that the ammonia is disengaged from the ammoniacal salts, at the negative surface in the Voltaic circuit; and I concluded that under this agency, it may be acted on in what is called the nascent state, when it was reasonable to conclude it would be more readily deoxigenated and combined with quicksilver.

On this view of the subject, I made a cavity in a piece of muriate of ammonia; into this a globule of mercury, weighing about fifty grains, was introduced. The muriate was slightly moistened, so as to be rendered a conductor, and placed on a plate of platina, which was made positive in the circuit of the large battery. The quicksilver was made negative by means of a platina wire. The action of the quicksilver on the salt was immediate; a strong effervescence with much heat took place. The globule in a few minutes had enlarged to five times its former dimensions, and had the appearance of an amalgam of zinc; and metallic crystallizations shot from it, as a centre, round the body of the salt. They had an arborescent appearance, often became coloured at their points of contact with the muriate; and when the connection was broken, rapidly disappeared, emitting ammoniacal fumes, and reproducing quicksilver.

When a piece of moistened carbonate of ammonia was used, the appearances were the same, and the amalgam was formed with equal rapidity. In this process of deoxidation, when the battery was in powerful action, a black matter formed in the cavity, which there is every reason to believe was carbonaceous matter from the decomposition of the carbonic acid of the carbonate.*

The strong attraction of potassium, sodium, and the metals of the alkaline earths for oxygen, induced me to examine whether their deoxidating powers could not be made to produce the effect of the amalgamation of ammonia, independently of the agency of electricity; and the result was very satisfactory.

When mercury, united to a small quantity of potassium, sodium, barium, or calcium, was made to act upon moistened muriate of ammonia, the amalgam rapidly increased to six or seven times its volume, and the compound seemed to contain much more ammoniacal basis than that procured by electrical powers.

As in these cases, however, a portion of the metal used for the deoxidation always remained in union in the compound; in describing the properties of the amalgam from ammonia, I shall speak only of that procured by electrical means.

The amalgam from ammonia, when formed at the temperature of 70° or 80°, is a soft solid, of the consistence of butter; at the freezing temperature it becomes firmer, and a crystallized mass, in which small facets appear, but having no perfectly defined form.† Its specific gravity is below 3, water being one.

When exposed to air it soon becomes covered with a white crust, which proves to be carbonate of ammonia.

When thrown into water it produces a quantity of hydrogen, equal to about half its bulk, and in consequence of this action the water becomes a weak solution of ammonia.

When it is confined in a given portion of air, the air enlarges considerably in volume, and the pure quicksilver re-appears. Ammoniacal gas, equal to one and a half or one and three-fifths of the volume of the amalgam is found to be produced, and a quantity of oxygen equal to one-seventh, or one-eighth of the ammonia disappears.‡

When thrown into muriatic acid gas, it instantly becomes coated with muriate of ammonia, and a small quantity of hydrogen is disengaged.

In sulphuric acid it becomes coated with sulphate of ammonia and sulphur.

I attempted by a variety of modes to preserve this amalgam. I had hoped by submitting it to distillation out of the contact of air, or water, or bodies which could furnish oxygen, to be able to obtain the deoxigenated substance which had been united to the quicksilver in a pure form; but all the circumstances of the experiment opposed themselves to such a result.

It is well known to persons accustomed to barometrical experiments, that mercury, after being once moistened, retains water with great perseverance, and can only be freed from it by boiling; and in the cases of the decomposition of

* The black matter which separates at the negative surface in the electrical experiments on the decomposition of potash or soda, and which some experimenters have found it difficult to account for, is I find carbonaceous, and dependent upon the presence of carbonic acid in the alkali.

† From the facet I suspect the form to be cubical. The amalgam of potassium crystallizes in cubes as beautiful, and in some cases as large as those of bismuth.

‡ This experiment confirms the opinions I have stated concerning the quantity of oxygen in ammonia; but as water is present, as will be immediately shewn, the data for proportions are not perfectly correct.

ammonia, when a soft amalgam had been kept continually moist, both internally and externally for some time, it could not be expected that all the water adhering to it should be easily removed

I wiped the amalgam as carefully as possible with bibulous paper; but even in this process a considerable portion of the ammonia was regenerated; I attempted to free it from moisture by passing it through fine linen, but a complete decomposition was effected, and nothing was obtained but pure quicksilver.

The whole quantity of the basis of ammonia combined in sixty grains of quicksilver, as is evident from the statements that have been made, does not exceed 1-200th part of a grain, and to supply oxygen to this scarcely 1-1000th part of a grain of water would be required, which is a quantity hardly appreciable, and which merely breathing upon the amalgam would be almost sufficient to communicate.

Hence, when an amalgam, which had been wiped by means of bibulous paper, was introduced into naphtha, it decomposed almost as rapidly as in the air, producing ammonia and hydrogen.

In oils it evolved hydrogen, and generated ammoniacal soap; and when it was introduced into a glass tube, closed by a cork, gas was rapidly formed, and the mercury remained free; and this gas, when examined, was found to consist of from about two-thirds to three-fourths ammonia, and the remainder hydrogen.*

That more moisture sometimes existed attached to the amalgam, when wiped as dry as possible by bibulous paper, than was sufficient for the effect of decomposition, I soon found by an experiment of distillation

About a quarter of a cubic inch of an amalgam nearly solid was wiped very dry, and introduced into a small tube; in this tube it was heated till the gaseous matter had expelled the quicksilver; the tube was then closed, and suffered to cool, when moisture, which proved to be a saturated solution of ammonia, had precipitated upon it

I have mentioned that the amalgams obtained from ammonia, by means of the metals of the fixed alkalies or alkaline earths, seemed to contain much more ammoniacal basis in combination than those procured by electricity: and when they are combined with the metals of the fixed alkalies or of the earths in any considerable quantities, they are much more permanent.

Triple compounds of this kind, when carefully wiped, scarcely produce any ammonia under naphtha, or oil, and may be preserved for a considerable time in closed glass tubes, a little hydrogen being the only product evolved from them.

I heated a triple amalgam obtained from ammonia by potassium, and which had been wiped by bibulous paper in a dry plate-glass tube over mercury; a considerable elevation of temperature was required before any gaseous matter was emitted, but the heat was raised till gas was rapidly formed, and the whole of the amalgam expelled from the tube: in cooling, the mercury rose very quickly in it, so that a great part of the gaseous matter had been either mercury or water, in vapour, or something which the mercury had absorbed in cooling The small quantity which was permanent, did not equal one-half the volume of the amalgam

On the idea that this gas might be a compound of hydrogen and nitrogen in the state of deoxigenation, I mixed a small quantity of oxygen gas with it, but no change of volume took place; I then exposed it to naphtha, when one-half of it was absorbed, which by the effect the naphtha produced upon turmeric must have been ammonia; the remaining gas analyzed was found to consist of the oxygen that had been introduced, and of hydrogen and nitrogen to each other in the proportion of nearly four to one

At first I was perplexed by this result, which seemed to prove the production of ammonia, independent of the presence of any substance which could furnish oxygen to it, and to show that its amalgamation was merely owing to its being freed from water, and combined with hydrogen; but a satisfactory solution of the difficulty soon offered itself Exposing the triple amalgam procured from ammonia by potassium to a concentrated solution of ammonia, I found that it had very little action upon it, and introducing the amalgam moistened by it into a glass tube, it

* In the experiment of the action of the amalgam upon air, the oxygen is probably absorbed by nascent hydrogen, and reproduces water which is dissolved by the ammonia

had nearly the same permanency as the amalgam which had been wiped before it was introduced, a little hydrogen only being evolved; but on heating the tube gaseous matter was rapidly generated, which proved to consist of two-thirds ammonia, and one-third hydrogen.

In the instance in which the amalgam had been wiped, a small quantity of solution of ammonia, and perhaps of potash, must have adhered to it; and though the amalgam does not act upon this powerfully at common temperatures, yet when the water is raised in vapour, it tends to oxigenate both the basis of ammonia, and potassium, and hence hydrogen is evolved, and volatile alkali produced.

I distilled an amalgam procured by potassium from ammonia, in a tube filled with the vapour of naphtha, and hermetically sealed, in the same manner as in the experiments for obtaining the metals of the earths, but in this case I procured ammonia, hydrogen, and nitrogen only, and pure mercury; and the residuum was potassium, which acted powerfully on the glass tube.

In another experiment of the same kind, I kept one part of the tube cool by ice, at the time the other part was strongly heated, but nothing condensable except mercury was produced, and the elastic products were the same as in the former instance.

I endeavoured to procure an amalgam from ammonia, to which no moisture could be supposed to adhere, by heating an amalgam of potassium in ammoniacal gas. The amalgam became covered with a film of potash, but it did not enlarge in its dimensions, and a considerable quantity of non-absorbable gas, which was found to consist of five parts of hydrogen, and one of nitrogen, was produced. The amalgam after this operation did not emit ammonia by exposure to air; hence it seems probable, that for the deoxigenation of ammonia, and the combination of its basis with mercury, the alkali must be in the nascent state, or at least in that condensed form in which it exists in ammoniacal salts, or solutions.

VI.—SOME CONSIDERATIONS OF GENERAL THEORY, CONNECTED WITH THE METALLIZATION OF THE ALKALIES AND THE EARTHS.

The more the properties of the amalgam obtained from ammonia are considered, the more extraordinary do they appear.

Mercury by combination with about 1-12000th part of its weight of new matter, is rendered a solid, yet has its specific gravity diminished from 13·5 to less than 3, and it retains all its metallic characters; its colour, lustre, opacity, and conducting powers remaining unimpaired.

It is scarcely possible to conceive that a substance which forms with mercury so perfect an amalgam, should not be metallic in its own nature;* and on this idea to assist the discussion concerning it, it may be conveniently termed ammonium.

But on what do the metallic properties of ammonium depend?

Are hydrogen and nitrogen both metals in the aëriform state, at the usual temperatures of the atmosphere, bodies of the same character, as zinc and quicksilver would be in the heat of ignition?

Or are these gases, in their common form, oxides, which become metallized by deoxidation?

Or are they simple bodies not metallic in their own nature, but capable of composing a metal in their deoxigenated, and an alkali in their oxigenated state?

These problems, the second of which was stated by Mr. Cavendish to me, and the last of which belongs to M. Berzelius, offer most important objects of investigation.

I have made some experiments in relation to them, but as yet unsuccessfully.

* The nature of the compounds of sulphur and phosphorus with mercury, favours this opinion; these inflammable bodies by combination, impair its metallic properties; cinnabar is a non-conductor, and it would seem from Pelletier's experiments, Ann. de Chimie, vol. xiii. p. 125, that the phosphuret of mercury is not metallic in its characters; charcoal is a conductor, and in plumbago carbon approaches very near to a metal in its characters, so that the metallic nature of steel does not militate against the reasoning in the text. The only facts which I am acquainted with that do militate against it, are the metallic characters of some of the sulphurets and phosphurets of the imperfect metals.

I have heated the amalgam of potassium, in contact with both hydrogen and nitrogen, but without attaining their metallization; but this fact cannot be considered as decisively for or against any one of these conjectures.

I mentioned in the Bakerian Lecture for 1807, that a modification of a phlogistic chemical theory might be defended on the idea that the metals and inflammable solids, usually called simple, were compounds of the same matter as that existing in hydrogen, with peculiar unknown bases, and that the oxides, alkalies, and acids were compounds of the same bases with water, and that the phenomena presented by the metals of the fixed alkalies might be explained on this hypothesis.

The same mode of reasoning may be applied to the facts of the metallization of the earths and ammonia, and perhaps with rather stronger evidences in its favour, but still it will be less distinct and simple, than the usually received theory of oxigenation, which I have applied to them.

The general facts of the combustion, and of the action of these new combustible substances upon water, are certainly most easily explained on the hypothesis of Lavoisier; and the only good arguments in favour of a common principle of inflammability, flow from some of the novel analogies in electro-chemical science.

Assuming the existence of hydrogen in the amalgam of ammonium, its presence in one metallic compound evidently leads to the suspicion of its combination in others. And in the electrical powers of the different species of matter, there are circumstances which extend the idea to combustible substances in general. Oxygen is the only body which can be supposed to be elementary, attracted by the positive surface in the electrical circuit, and all compound bodies, the nature of which is known, that are attracted by this surface, contain a considerable proportion of oxygen. Hydrogen is the only matter attracted by the negative surface, which can be considered as acting the opposite part to oxygen; may not then the different inflammable bodies, supposed to be simple, contain this as a common element?

Should future experiments prove the truth of this hypothesis, still the alkalies, the earths, and the metallic oxides will belong to the same class of bodies. From platina to potassium there is a regular order of gradation as to their physical and chemical properties, and this would probably extend to ammonium, could it be obtained in the fixed form. Platina and gold in specific gravity, degree of oxidability, and other qualities, differ more from arsenic, iron, and tin, than these last do from barium and strontium. The phenomena of combustion of all the oxidable metals are precisely analogous. In the same manner as arsenic forms an acid by burning in air, potassium forms an alkali and calcium an earth; in a manner similar to that in which osmium forms a volatile and acrid substance by the absorption of oxygen, does the amalgam of ammonium produce the volatile alkali; and if we suppose that ammonia is metallized, by being combined with hydrogen, and freed from water, the same reasoning will likewise apply to the other metals, with this difference, that the adherence of their phlogiston or hydrogen, would be exactly in the inverse ratio of their attraction for oxygen. In platina* it would be combined with the greatest energy; in ammonium with the least; and if it be separable from any of the metals without the aid of a new combination, we may expect that this result will be afforded by the most volatile and oxidable, such as arsenic, or the metals of the fixed alkalies, submitted to intense heat, under electrical polarities, and having the pressure of the atmosphere removed.

Whatever new lights new discoveries may throw upon this subject, still the facts that have been advanced shew that a step nearer at least has been attained towards the true knowledge of the nature of the alkalies and the earths.†

* The common metallic oxides are lighter than their bases, but potash and soda are heavier; this fact may be explained on either theory; the density of a compound will be proportional to the attraction of its parts. Platina, having a weak affinity for oxygen, cannot be supposed to condense it in the same degree as potassium does; or if platina and potassium be both compounds of hydrogen, the hydrogen must be attracted in platina, with an energy infinitely greater than in potassium. Sulphuric acid is lighter than sulphur; but phosphoric acid (where there is a stronger affinity is heavier than phosphorus. The oxide of tin (wood tin) is very little inferior to tin in specific gravity. In this instance the metallic base is comparatively light, and the attraction for oxygen strong; and in a case when the metal is much lighter and the attraction for oxygen stronger, it might be expected *à priori* that the oxide would be heavier than the base.

† Since the facts in this Paper were communicated to the Royal Society, I have seen

Something has been separated from them which adds to their weight; and whether it be considered as oxygen, or as water, the inflammable body is less compounded, than the uninflammable substance resulting from its combustion.

Other hypothesis might be formed upon the new electro-chemical facts, in which still fewer elements than those allowed in the antiphlogistic or phlogistic theory might be maintained. Certain electrical states always coincide with certain

an account of some very curious experiments of MM. Gay Lussac and Thenard, (in No. 148 of the *Moniteur*, for 1808, which I have just received,) from one of which they have concluded, "that potassium may be a compound of hydrogen and potash."

These gentlemen are said to have heated potassium in ammonia, and found that the ammonia was absorbed, and that hydrogen gas equal to two-thirds of its volume appeared, and that the potassium by this process had become of a grayish-green colour. By heating this grayish-green substance considerably, two-fifths of the ammonia were again emitted, with a quantity of hydrogen and nitrogen corresponding to one-fifth more, and by adding water to the mixture, and heating it very strongly again, they obtained the remainder of the ammonia, and nothing but potash was left.

In these complex processes, the phenomena may be as easily explained on the idea of potassium being a simple, as that of its being a compound substance; nor when the facts that have been stated in this paper and those about to be stated, are considered, can the view of these distinguished chemists, as detailed in the notice referred to, be at all admitted.

Potash, as I have found by numerous experiments, has no affinity for ammonia, for it does not absorb it when heated in it; it is not therefore (allowing their theory) possible to conceive that a substance having no attraction for potash, should repel from it a substance which is intimately combined with it, and which can be separated in no other way.

A part of the hydrogen evolved in their experiment, may be furnished by water contained in the ammonia; but it is scarcely possible that the whole of it can be derived from this source, for on such an idea the ammonia must contain more than half its weight of water. There is however no evidence that the whole of the hydrogen may not be furnished by the decomposition of the volatile alkali itself. Potassium in its first degree of oxigenation, may have an affinity for nitrogen, or potassium may expel a portion of hydrogen at the moment of its combination with ammonium; and as the whole of the ammonia cannot be regenerated without the presence of water, hydrogen and a little oxygen may be furnished to the remaining elements of the ammonia, from the water, and oxygen to the potassium.

Even before the conclusion was formed, that a metallic substance is decomposed in this experiment, it should have been proved that the nitrogen had not been altered.

That mere potash, combined with hydrogen, cannot form potassium, is I think shown by an experiment which I tried, in consequence of the important fact lately ascertained by MM. Gay Lussac and Thenard, of the deoxidation of potash by iron.

An ounce of potash was kept in ignition for some time in an iron tube, ground into a gun barrel in which one ounce and a half of iron turnings were ignited to whiteness; a communication was opened, by withdrawing a wire which closed the tube containing the potash, between that alkali and the metal.

As the potash came in contact with the iron, gaseous matter was developed, which was received in a proper apparatus, and though some of it was lost by passing through the potash into the atmosphere, yet nearly half a cubic foot was preserved, which proved to be hydrogen. In the tube were found two products, one in the quantity of a few grains, containing potassium, combined with a small quantity of iron, and which had sublimed in the operation, and the other a fixed white metallic substance which consisted of an alloy of iron and potassium.

The first of these substances burnt when thrown upon water; and in its other characters resembled pure potassium, except that its specific gravity was greater, its colour less brilliant, and when it tarnished in the atmosphere, it became of a much deeper colour than pure potassium.

Now potash that has been ignited, is the purest form known of this alkali; but on MM. Gay Lussac's and Thenard's theory, this potash must contain water, not only sufficient to furnish hydrogen to metallize the alkali, but likewise the quantity disengaged: dry potash then, as it is procured in our experiments, must on this theory be a compound, containing a considerable quantity of matter which can furnish hydrogen; and what would be its form or properties if deprived of this matter we are wholly unable to judge, which brings this question to the general question discussed in the text.

Potassium I find may be produced readily from dry ignited potash in electrical experiments; and the result of the combustion of potassium in oxygen gas is an alkali, so dry that it produces violent heat, and ebullition when water is added to it.

chemical states of bodies. Thus acids are uniformly negative, alkalies positive, and inflammable substances highly positive; and as I have found, acid matters when positively electrified, and alkaline matters when negatively electrified, seemed to lose all their peculiar properties and powers of combination. In these instances the chemical qualities are shewn to depend upon the electrical powers; and it is not impossible that matter of the same kind, possessed of different electrical powers, may exhibit different chemical forms.*

In MM. Gay Lussac's and Thenard's experiment on the action of potassium on ammonia, the hydrogen disengaged in the first process, and that existing in the ammonia disengaged in the second process, exactly equals the whole quantity contained in the ammonia. But there is no proof of any hydrogen being disengaged from the potassium, for the ammonia lost is not generated, nor potash formed, but by the addition of a substance, consisting of oxygen and hydrogen: and as the three bodies concerned in this experiment are potassium, ammonia, and water, the result ought to be potash, ammonia, and a quantity of hydrogen, equal to that evolved by the mere action of water on potassium, which is said to be the case.

Even if there were no other proofs, the chemical properties of potassium are so wholly unlike those that might be expected from a compound of potash and hydrogen, that they are almost sufficient to decide the question. Potassium acts upon water with much more energy than potash, and produces much more heat in it; and yet if a compound of hydrogen, the affinity of potash for water must be diminished by its affinity for hydrogen, to say nothing of the quantity of heat, which ought (on the common theory of capacity for heat) to be carried off by this light inflammable gas.

Potassium burns in carbonic acid, and precipitates charcoal from it; whereas hydrogen electrized with carbonic acid, converts it into gaseous oxide of carbon.

Potash has a very slight attraction for phosphorus; but potassium has a very strong affinity for it, so as to separate it from hydrogen, and according to MM. Gay Lussac and Thenard, with the phenomena of inflammation. Potash has no affinity for arsenic, yet from the experiments of these gentlemen, it appears that potassium separates arsenic from arseniuretted hydrogen; and hydrogen, which is supposed by them to exist in both compounds, can have no affinity for hydrogen, nor can hydrogen in one form, be supposed capable of separating arsenic from hydrogen in another form.

Could not the experiment of MM. Gay Lussac and Thenard be explained, except on the supposition of the hydrogen being derived from the potassium, it would be a distinct fact in favour of the revival of the theory of phlogiston. It would not prove, however, that potassium is composed of hydrogen and potash, but that it is composed of hydrogen and an unknown basis; and that potash is this basis united to water.

* Phil. Trans. 1807, part 1. p. 10. The amalgam obtained from ammonia offers difficulties to both the phlogistic and antiphlogistic hypotheses. If we assume the phlogistic hypothesis, then we must assume that nitrogen, by combining with one-fourth of its weight of hydrogen can form an alkali, and by combining with one-twelfth more, can become metallic. If we reason on the antiphlogistic hypothesis, we must assert, that though nitrogen has a weaker affinity for oxygen than hydrogen, yet a compound of hydrogen and nitrogen is capable of decomposing water.

The first assumption is however by far the most contradictory to the order of common chemical facts; the last, though it cannot be wholly removed, is yet lessened by analogies. Thus alloys in general, and inflammable compounds, are more oxidable than the simple substances that compose them. Sulphuret of iron at common temperatures decomposes water with facility, whereas sulphur under the same circumstances, has no action on water, and iron a very small one. The compound of phosphorus and hydrogen is more inflammable than either of its constituents.

Should a new theory of the dependence of the chemical forms of matter upon electrical powers be established, the facts belonging to ammonium would admit of a more easy solution. Ammonium might be supposed to be a simple body, which, by combining with different quantities of water, and in different states of electricity, formed nitrogen, ammonia, atmospherical air, nitrous oxide, nitrous gas, and nitric acid.

Water, on this idea, must be supposed a constituent part of all the different gases; but its electricities in oxygen and hydrogen would probably be the very reverse of what they have been supposed by M. Ritter, and some ingenious English enquirers.

Water positively electrified would be hydrogen, water negatively electrified oxygen; and as in the physical experiments of temperature, ice, added to certain quantities of steam by an equilibrium of heat produces water, so in the chemical experiment of the generation of water the positive and negative electricity of oxygen and hydrogen in certain proportions would annihilate each other, and water alone be the result. At all events ammonium, whether simple or compound, must be considered as owing its attraction for oxygen to its highly positive electrical state, which is shown by its powerful determination to the negative surface in the Voltaic circuit.

I venture to hint at these notions; but I do not attach much importance to them; the age of chemistry is not yet sufficiently mature for such discussions; the more subtile powers of matter are but just beginning to be considered; and all general views concerning them, must as yet rest upon feeble and imperfect foundations.

Whatever be the fate of the speculative part of the inquiry, the facts however will, I hope, admit of many applications, and explain some phenomena in nature.

The metals of the earths cannot exist at the surface of the globe; but it is very possible that they may form a part of the interior; and such an assumption would offer a theory for the phenomena of volcanoes, the formation of lavas, and the excitement and effects of subterraneous heat,* and would probably lead to a general hypothesis in geology.

The luminous appearance of those meteors connected with the fall of stones, is one of the extraordinary circumstances of these wonderful phenomena. This effect may be accounted for, by supposing that the substances which fall, come into our atmosphere in a metallic state; and that the earths they principally consist of are a result of combustion; but this idea has not the slightest connexion with their origin or causes.

* Let it be assumed that the metals of the earths and alkalies, in alloy with common metals, exist in large quantities beneath the surface, then their accidental exposure to the action of air and water, must produce the effect of subterranean fire, and a produce of earthy and stony matter analogous to lavas.

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LECTURE VI.

OF MANURES OF VEGETABLE AND ANIMAL ORIGIN.—OF THE MANNER IN WHICH THEY BECOME THE NOURISHMENT OF THE PLANT.—OF FERMENTATION AND PUTREFACTION.—OF THE DIFFERENT SPECIES OF MANURES OF VEGETABLE ORIGIN; OF THE DIFFERENT SPECIES OF ANIMAL ORIGIN.—OF MIXED MANURES.—GENERAL PRINCIPLES WITH RESPECT TO THE USE AND APPLICATION OF SUCH MANURES.

THAT certain vegetable and animal substances introduced into the soil accelerate vegetation and increase the produce of crops, is a fact known since the earliest period of agriculture; but the manner in which manures act, the best modes of applying them, their relative value and durability, are still subjects of discussion. In this Lecture I shall endeavour to lay down some settled principles on these objects; they are capable of being materially elucidated by the recent discoveries in chemistry; and I need not dwell on their great importance to farmers.

The pores in the fibres of the roots of plants are so small, that it is with difficulty they can be discovered by the microscope; it is not therefore probable, that solid substances can pass into them from the soil. I tried an experiment on this subject; some impalpable powdered charcoal procured by washing gun-powder was placed in a phial containing pure water, in which a plant of peppermint was growing: the roots of the plant were pretty generally in contact with the charcoal. The experiment was made in the beginning of May, 1805; the growth of the plant was very vigorous during a fortnight, when it was taken out of the phial: the roots were cut through in different parts; but no carbonaceous matter could be discovered in them, nor were the smallest fibrils blackened by charcoal, though this must have been the case had the charcoal been absorbed in a solid form. *

* Although there can be no doubt that plants take up almost all their nourishment in the liquid or gaseous state, it is by no means certain that they are altogether incapable of taking up solid matter. Many experiments on infecting grain with the bunt and smut fungi appear to be explicable only on this supposition; thus when the seeds of sound wheat are rubbed with the black powder of the smut before being sown, the plants they produce are uniformly affected with smut; and this can scarcely be supposed to take place otherwise than by the absorption of the solid though extremely minute sporules of the fungus through the roots.

In speculating on the food of plants, it has been a common error to exaggerate the amount taken up in the liquid form, and overlook what is acquired in the state of gas and vapour. The experiments of Hales and others on the transpiration of plants shew that a great deal of water is absorbed by them, and if this is acquired from the soil through the roots, it follows, that a good deal of

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